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Crop rotation, weeds,
Insect-pests, Cereals,
Soybeans, Corn, popcorn,
Sorghum, wheat, ryes,
Oats, Barleys, flax,

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GRAIN CROPS

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GRAIN CROPS

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TO THE MEMORY OF

MY MOTHER

AMANDA E. WILSON

AND WIFE

FLORENCE MUNSON WILSON

PREFACE

For a period of 18 years, the author, working at the University of Minnesota, taught a course treating the various phases of the production of grain crops. A series of outlines was developed for use in student instruction. These outlines were revised many times and finally were expanded into the present text.

The book is designed for use either as a beginning course in grain crops or to follow more elementary treatment. The subject matter is arranged in what is believed to be a logical sequence, with the more general phases, as related to all crops, considered in the early chapters and the more detailed discussion of individual crops reserved for the later chapters. Where it seems desirable, repetition is used for clarification. For example, while there is a chapter on diseases, it has been found advisable to make reference to certain diseases at the time of discussing a given crop. To the teacher, the advantages of this arrangement are obvious. The text ends with a fairly complete chapter on improvement, the ultimate objective of the plant breeder.

The text should prove useful, not only to the student, but also to the layman who desires information on practical grain production.

The more advanced students will find that the liberal use of selected references offers a challenge to all levels of previous preparation. The instructor should gauge the use of these references according to the degree of attainment achieved by his students.

A few pertinent questions are listed at the close of each chapter. These are given as a guide to study and are not intended to be complete. It is expected that the instructor will develop additional questions and problems that may aid in directing the learning of the student.

Assistance and advice have been given by a number of workers. Particular credit is due Dr. H. K. Hayes, chief of the Division of Agronomy and Plant Genetics, University of Minnesota, for painstakingly reading the entire manuscript and offering many constructive criticisms.

The author is indebted to the following workers in the United States Department of Agriculture who have read portions of the manuscript and have freely advised in its preparation: Drs. O. S. Aamodt,

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Special recognition is given to the author's late wife, Florence Munson Wilson, who by her unfailing assistance and enthusiasm made it possible to prepare the manuscript. During the period when it was impossible to secure outside stenographic help, Mrs. Wilson typed most of the chapters and aided greatly in the arduous task of proofreading, editing, and shaping the material.

STATE COLLEGE, PA.
January, 1948

HAROLD K. WILSON

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CHAPTER I

GRAIN CROPS AND ENVIRONMENT

Successful teachers of agronomy have learned to appreciate the value of teaching those principles which are basic to an understanding of factual information. The student who understands principles is in a far better position to make the best use of his knowledge than the student who has memorized a number of data without really understanding their usefulness and application.

In a study of the grain crops it seems advisable to review some of the fundamentals of botany and to coordinate the sciences with the more applied phases of crop production. Properly related to the field of crop production, the sciences of botany and chemistry open wide the doors of knowledge leading to a mastery of crop science.

SIGNIFICANCE OF PLANTS

The student of today realizes that all life on this earth is dependent upon the plant organism. The plant through its ability to incorporate energy from the sun fills an essential gap which no animal is able to bridge. The process of transferring radiant energy to latent energy available for the use of the animal is accomplished by the green plant through a process known as *photosynthesis*.

Photosynthesis.—The word photosynthesis is derived from a combination of two words, *photo*, meaning light, and *synthesis*, to put together. In short, photosynthesis is a process of putting together carbon dioxide and water in the presence of light. This reaction is the result of the activity of the green chloroplasts which are found in the living cells of green plants. Plants such as the dodders *Cuscuta* spp., or fungus diseases such as black stem rust, which do not contain chlorophyll, are unable to manufacture food and, like animals, are dependent upon green plants for their sustenance.

While there has been some debate as to the exact nature of the chemical processes, for the purpose of illustration, photosynthesis may be represented as follows:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2 \uparrow$$

To this equation should be added 673 kg. cal. of energy derived from

the sun. Thus six molecules of carbon dioxide unite with six molecules of water, in the presence of sunlight, and produce one molecule of a simple sugar such as glucose.

Starch is the common type of carbohydrate stored by grain crops, such as corn, oats, wheat, and barley. The starch is synthesized from glucose as follows:

$$nC_6H_{12}O_6 \longrightarrow (C_6H_{10}O_5)n + nH_2O$$

The small letter n is used to denote that a large number of glucose molecules is required to form starch with the elimination of n molecules of water. The exact number of molecules is unknown, so the letter n is used rather than a number.

Some plants, such as the sugar beet, store energy as sugar. This sugar or sucrose (a disaccharide) is formed from the simple sugars (monosaccharides) in the presence of the enzyme *sucrase* as follows:

$$C_6H_{12}O_6 + C_6H_{12}O_6 \longrightarrow C_{12}H_{22}O_{11} + H_2O$$

The newly formed sugar is the type commonly purchased as cane or beet sugar, according to the plant from which it is processed.

Respiration.—Only plants with green chloroplasts can carry on photosynthesis, but all living plants and animals carry on respiration. While photosynthesis is an energy-storing process, respiration is an energy-releasing process. The energy stored in grain would be of little value to man if it were not possible to release it for his use.

There are two types of respiration, *aerobic respiration* and *anaerobic respiration.* Aerobic respiration occurs in the presence of atmospheric oxygen and is the type utilized by man, in which he breathes in oxygen which breaks down (oxidizes) the energy-bearing foods he has eaten. Anaerobic respiration takes place in the absence of atmospheric oxygen.

The aerobic respiration process is the reverse of the photosynthetic formula and may be illustrated as follows:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2 \uparrow$$

Not shown in the above equation is the 673 kg. cal. of energy. This energy is released in digestion and in part is utilized by the animal or plant. If the animal is fed a greater quantity of energy-bearing feed than is needed for ordinary life processes, the excess energy may be stored in the form of fat. Thus when a farmer feeds his hogs an abundance of starchy feed, such as corn, he is making it possible for the animals to gain in weight through a storage of the surplus energy released from the corn.

Anaerobic respiration may be illustrated by fermentation, a process of great importance to agriculture. A simple illustration of fermentation follows:

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + 25 \text{ kg.cal.}$$

This reaction occurs in the presence of the enzyme *zymase*. It is typical of the reactions occurring throughout life. The yeasts and

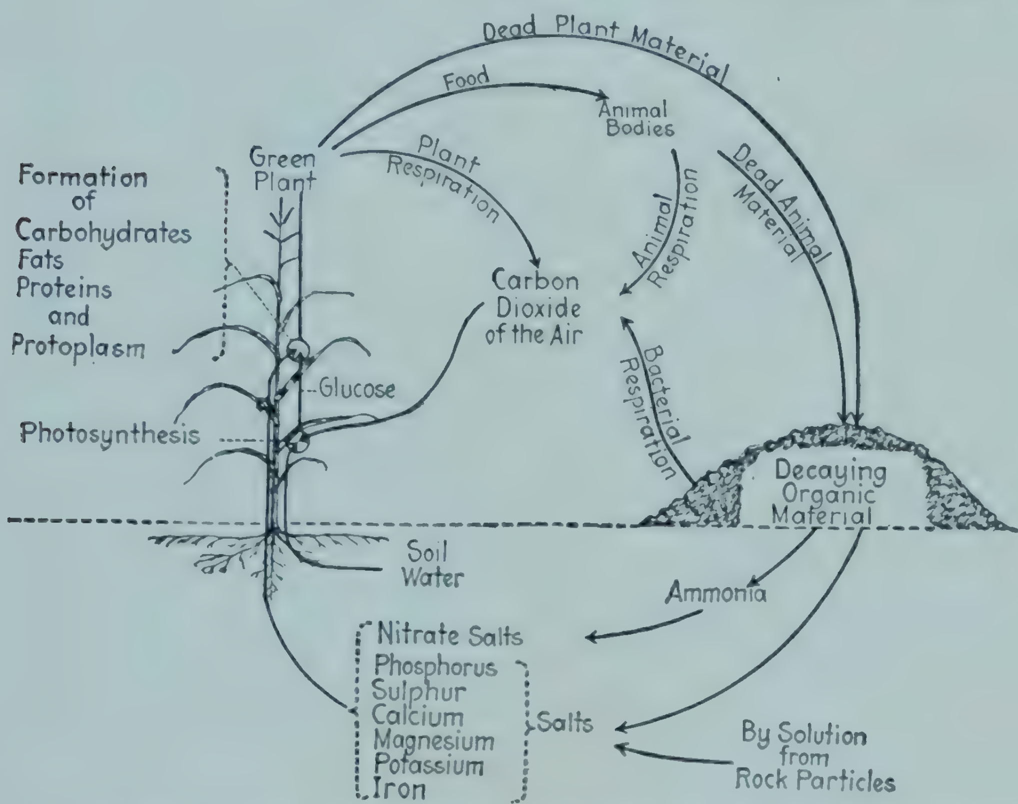


FIG. 1.—The organic cycle. History of the construction and disintegration of the important organic substances found in plants. (*From E. W. Sinnott.*)

several types of fungi can bring about fermentation. One has but to mix up a slop of grain to observe the quickly developing sour smell, an indication that fermentation has occurred.

In fermentation the process does not completely release the stored energy, as occurs in respiration. The product ethyl alcohol, C_2H_5OH, is rich in energy, while the products of respiration in atmospheric oxygen, carbon dioxide, and water, have no energy value.

Grain plant seedlings can develop only in the presence of atmospheric oxygen, and a primary reason for early tillage is to aerate the soil. If the soil is heavy and wet, damage may occur quickly as the plants are deprived of their essential supply of oxygen.

The rapid respiration and subsequent release of energy is the cause

of grain heating in the bin if it has been stored before it has dried thoroughly. All living seeds respire, but the action is greatly slowed with desiccation, so that normally the heat released is dissipated before damage occurs.

THE FEEDING OF PLANTS

In a sense, the preceding discussion of photosynthesis and respiration is related to the feeding of plants. The utilization of the various chemi-

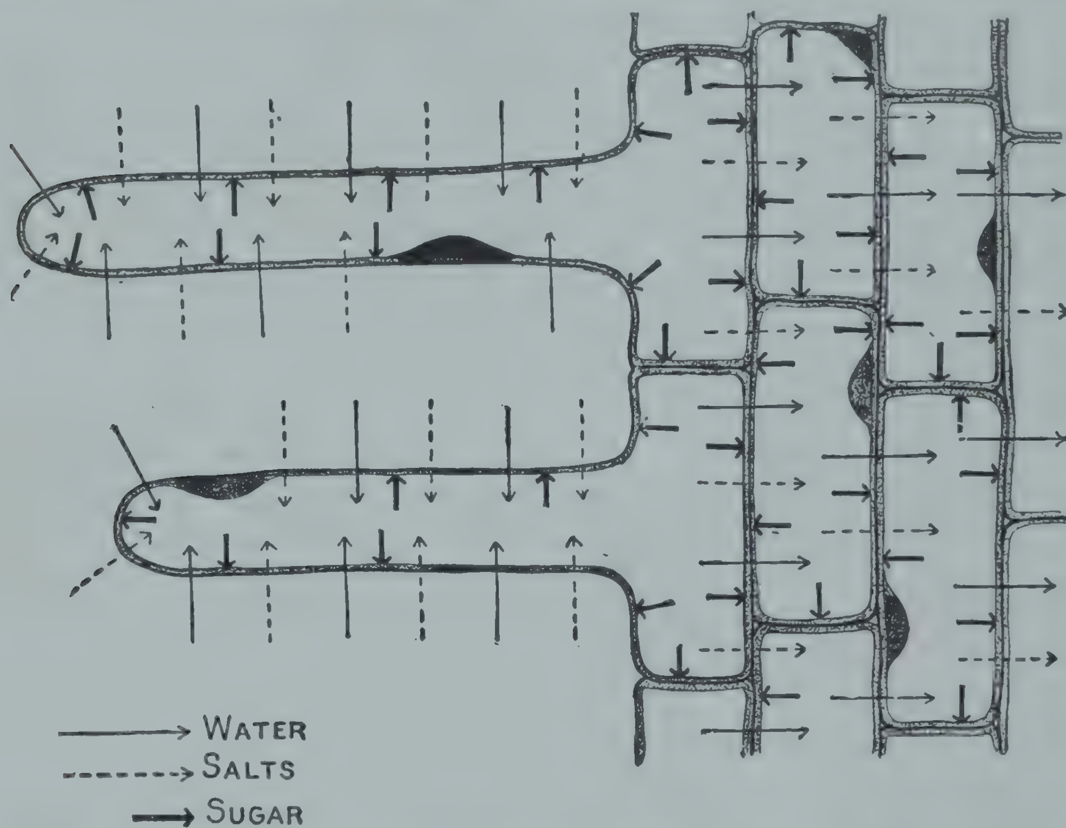


FIG. 2.—Movement of water and dissolved substances into the root. Diagram showing the entrance of water and salts into two root hairs and their passage thence through the cortical cells of the root. The cytoplasmic membranes are readily permeable to water and salts but prevent the passage of the sugar dissolved in the cell sap. (*From E. W. Sinnott.*)

cal elements whether derived from the air or the soil is a process of plant feeding. When Dr. C. G. Hopkins stated his Formula of C. H O P K I N S Ca Fe Mg (C. Hopkins café mighty good), he gave a plan that made it relatively easy for students to learn the then accepted elements essential to plant growth. Today we know that Dr. Hopkins's formula was not inclusive. There is evidence to show that to this list must be added boron, manganese, zinc, copper, and probably many others. While these latter elements are known as *trace elements* because but trace quantities are necessary, their total absence may cause serious deficiencies in plant growth. For example, the addition of small quan-

tities of boron has resulted in the control of certain plant diseases. Much remains to be learned about the need of these so-called *minor elements.*

The preceding discussion of photosynthesis illustrates the utilization of carbon, hydrogen, and oxygen. Some four-fifths of the atmosphere is nitrogen, a most important element since it is the principal constituent of the high-priced protein feeds. Nitrogen may be added to the soil through fertilizers, or it may be incorporated by properly inoculated legumes as a result of the ability of symbiotic bacteria to fix nitrogen.

The mineral elements were generally present in the virgin fertile mineral soils. Through cropping, leaching, and erosion these have been depleted from many soils, and it is necessary to replenish them by the application of various types of fertilizer. With proper rotation, the feeding of livestock, and the careful utilization of crop residues and barnyard manure, the farmer may delay the time when it is necessary to purchase commercial fertilizers. The time is delayed only, and more and more farmers are finding it profitable to institute a planned program of fertilization such as is almost universal in many sections of the country. For the best growth of grain crops, large quantities of nitrogen and phosphorus are required. These two elements are most likely to benefit the average soil, although other elements may be lacking in many areas, potash in particular being needed on many of the nation's soils. A careful soil analysis and farm *trials* are necessary to determine the need for fertilizers.

THE CYCLE OF PLANT GROWTH

A given species of plants may be thought of as having a definite cycle of growth, carrying it from seed stage to seed stage. In general, the phases of this cycle are (1) germination, (2) seedling growth, (3) active or developmental growth, (4) reproduction, (5) maturation, and (6) dormancy. Each of these parts of the cycle presents certain problems pertinent to crop production.

Germination.—The ability to germinate is based upon both genetic and physiologic factors. The proper maturation and storage of seeds under favorable environmental conditions have much to do with their ability to germinate. If it is assumed that the seed was stored properly, it may be expected to germinate when placed under the proper environmental conditions of heat, water, and aeration. For example, corn is not planted until the ground is warm, while wheat, oats, barley, and flax may be seeded in soil that is rather cold. Usually in the spring of the year, when most small grains are planted, seeding must be delayed

until the excess water has been drained or evaporated from the soil. The presence of an excess of water is closely allied to aeration, since a wet soil will not possess sufficient oxygen for optimum germination. This is one of the most common causes of poor germination of seeds, particularly of corn, during a period of cold, rainy weather. It must be remembered that unfavorable environmental conditions, such as the presence of disease organisms, may prevent normal germination.

Seedlings.—The cultivated crops such as corn and the sorghums respond to tillage in their early stages of growth, and it is important that tillage be as deep and as close to the plants as possible so as to provide good aeration to the developing roots. In the small-grain crops, the seedling stage is important in that a favorable environment may result in the development of many tillers or stools and thus increase the number of potential fruiting stems.

Active or Developmental Growth.—It is difficult to differentiate between the seedling stage and that of active growth. During active growth the plant should be so cultivated and fertilized that there is no interruption in its vital growth processes, as a drought period at this time may greatly reduce the yield. It is in this stage that the small-grain plant joints and heads and the corn and sorghum plants elongate rapidly and prepare for the production of flowers. The judicious use of fertilizers may speed growth in this stage of development and result in less damage from the frequent periods of hot weather which may menace the small-grain crops in particular

Reproduction.—It is Nature's rule that the plant perpetuate its kind. In the annual seed-bearing plant, the formation of seed is essential to reproduction. Early seeding and rapid growth are desirable to avoid the hot summer weather at the time when the grain crop produces its flowers. This is the most critical stage in the plant cycle, as a few hot days may result in poor fertilization and great reduction in the yield of grain.

Most of the small-grain crops are self-pollinated, *i.e.*, the flowers contain both male and female organs, and fertilization usually occurs within the individual flower. Of the grain crops, corn and rye are cross-pollinated; pollen from one plant is carried by the wind to the flowers of another plant. The sorghums have both male and female flowers on the flowering stalk, and while self-pollination is normally more frequent than cross-pollination, considerable cross-pollination may occur.

Maturation.—Following pollination and fertilization, the embryo develops and the seed is formed. During the active development of the

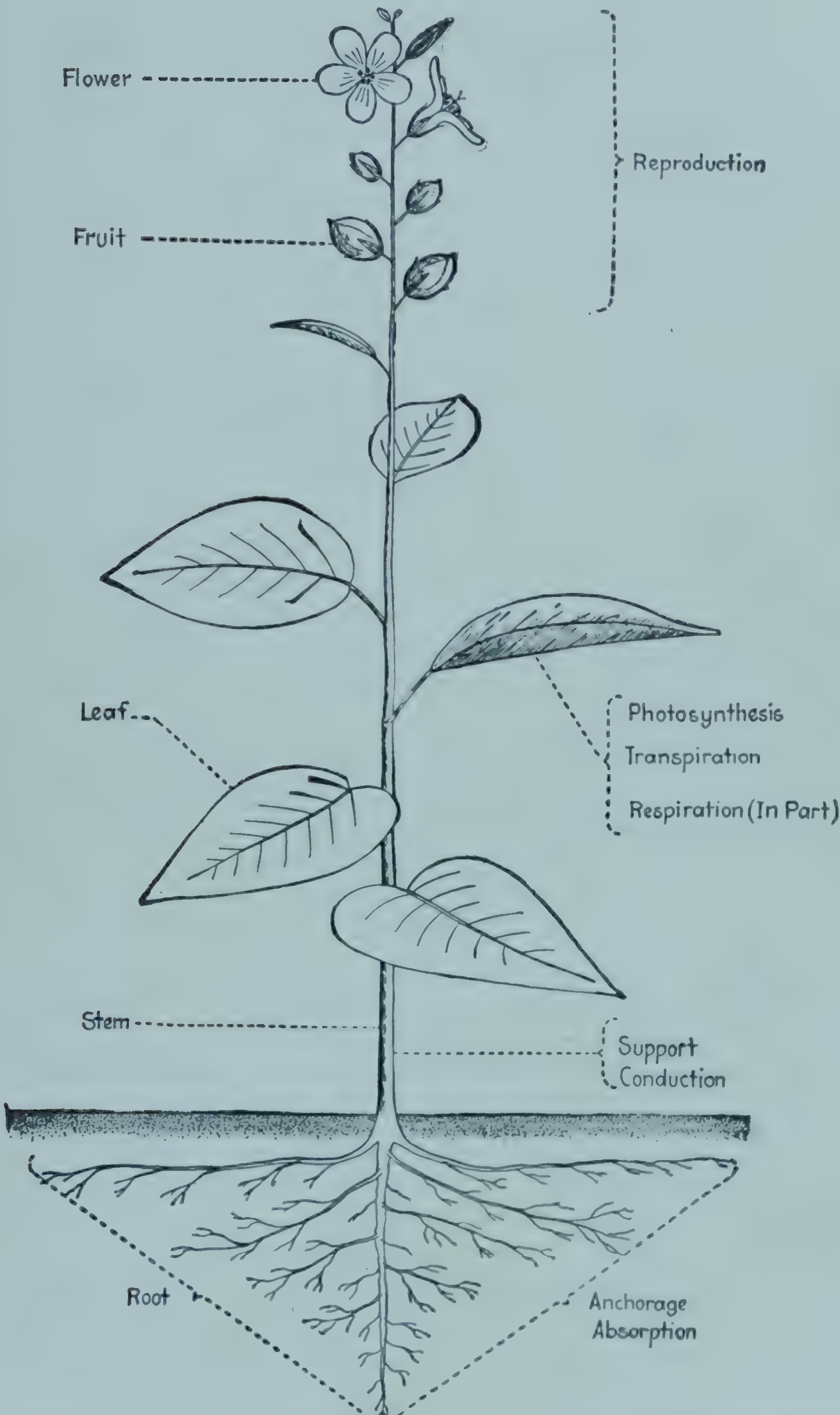


FIG. 3.—The important structures and functions of a seed plant, illustrated diagrammatically. (*From E. W. Sinnott.*)

seed it contains much water, but as maturity approaches, the water content is gradually reduced until the seed reaches a stage when it may be said to be mature. This is Nature's method of carrying the species through unfavorable environmental periods such as a period of drought or cold.

Many agronomic problems are related to the maturation of grain crops. The advent of the combine in the more humid areas created new problems of grain storage. When the grain contains too much water, respiration is proceeding rapidly and damage or complete crop loss may occur. In northern sections of the corn belt a primary concern of the farmer is to speed the growth of his corn so that it may mature before the first frost in the fall. Through the efforts of the plant breeder it has been possible to shorten the number of days required to mature corn, and this has resulted in a northward movement of the corn-producing areas.

Dormancy.—The period of dormancy is a natural follow-up of maturation. Some seeds have a period of after-ripening and will not germinate even when placed under favorable conditions. Generally this period is short for the grain crops, although trouble may be experienced where winter wheat is seeded after harvest. Whitcomb[1] noted the dormancy period of newly harvested wheat, oats, and barley but found that this did not prevent the obtaining of good stands in the field. Dormancy, which to a certain extent is a varietal characteristic, may aid in preventing premature sprouting of the kernel during periods of wet weather while the grain is awaiting threshing.

ENVIRONMENTAL FACTORS

While the response of different species of plants is dependent upon their genetic make-up, it is known that the factors of environment play a most important part in crop production. Each of the grain species is directly affected by the environment in which it is grown. In fact these factors limit the growing of the species to certain sections of the world. The most important factors of environment are (1) soil, (2) rainfall, (3) temperature and length of growing season, (4) light, and (5) air movements.

The Soil.—The soil, which has been referred to as the home of the plant, is a basic natural resource. A fertile soil is essential to satisfactory crop production. The wealth of America is due in no small part to its enormous areas of fertile soils. The fertile areas of the Great Plains

[1] Whitcomb, W. O., Germination of Newly Threshed Grain, *Proc. Assoc. Official Seed Analysts*, 14–15 Annual meeting, p. 84, 1923.

and of the Palouse country of the Northwest are typical of outstanding soils especially suited to the production of wheat. The rich, loamy soils of the corn belt were ideal for corn production. Today these soils are not so rich as when man found them. Many are partially lacking in one or more of the elements of fertility, others have been subjected to ruinous erosion. In many sections much destruction of basic resources has occurred. Various interested agencies are conducting conservation campaigns, and it is essential that wastes be stopped and that the fertility be maintained through the judicious use of fertilizers, proper crop rotation, and erosion control.

Sandy soils of varying degrees of fertility are found in many areas. In general, these soils if low in organic matter and nutrients are not well suited to grain production. However, if supplied with the necessary plant food, they may be used successfully as is being done in many areas. The small grains in particular tend to produce plants that are short and unproductive when grown on the more sandy soils. This is especially true in years when rainfall is not abundant.

The Rainfall.—Much water is required to produce a grain crop. In the classic work of Briggs and Shantz[1] it was shown that, under Colorado conditions, the number of pounds of water required to produce one pound of dry matter was as follows: corn, 368; oats, 597; wheat, 513; barley, 534; rye, 685; and the sorghums, 322.

From these data it is evident why so much water is required during the crop season. It should be noted also that the sorghums require considerably less water than the other crops listed. This explains why the sorghums are grown extensively in the drier areas of the crop-producing regions.

Areas that receive less than 10 in. of annual rainfall are considered to be unsuited for crops except where it is possible to irrigate. As a rule, an annual rainfall of at least 20 in. is necessary for grain crops. Most of the small grains are produced in areas with an annual rainfall between 20 and 40 in. In the drier areas where the rainfall is between 10 and 20 in., it is possible to grow grain crops by the use of summer fallow. This means that the land is cropped every other year and that the rainfall for 2 years is utilized in the growing of one crop.

The distribution of the rainfall is of great importance. If most of the precipitation comes during the winter months, it is of relatively little value to crops. In parts of the northern Great Plains, approximately 80 per cent of the total rainfall comes during the growing season,

[1] Briggs, Lyman J., and H. L. Shantz, Water Requirements of Plants, *U.S. Dept. Agr. Bur. Plant Industry Bull.* 285, 1913.

making it possible to grow the small grains with a minimum of precipitation. Much of the excess rainfall of the southeastern sections of the United States is of little value as it runs off and often causes destructive erosion.

Temperature and Length of Growing Season.—The period between the date of the last killing frost in the spring and the first killing frost in the autumn is known as the *growing season.* While some crops can withstand frosts, most of the grain crops are killed by freezing weather. Exceptions are winter wheat, barley, and oats, as will be pointed out in the discussion of these specific crops.

The small grains as a class are capable of germinating and making their early growth under cool, moist conditions. For this reason spring grains are planted, as a rule, just as early as it is possible to prepare a good seedbed. Usually, the wet soil conditions following the disappearance of frost will prevent too early seeding. The time of seeding winter grains will be discussed in later chapters. The small grains, including flax, may often endure a hard freeze without great injury. In some instances, no damage may occur; in others, the crop may be injured but tends to recover rather quickly.

Corn and the sorghums are more sensitive to cold soils and should not be planted until the ground is warm. The sorghums are not so tolerant to cold as corn. In northern areas it is important to plant corn as early as possible since the shorter growing season increases the danger of losses from fall frosts. Both corn and the sorghums develop most rapidly under somewhat warmer conditions than the small grains. In fact, small grains are favored by relatively cool weather, especially during the time of heading and flowering. Corn, on the other hand, does best if it is rather warm with an abundance of soil moisture.

Light.—While light is an environmental factor of importance, it is not likely to be a limiting factor in grain production. Even during cloudy weather sufficient light filters through to provide normal growth. It is believed, however, that the prevalence of clear days in the Northern Plains region is conducive to the high-quality grain that is produced. The occurrence of cloudy days with high humidity favors the development of certain plant diseases, particularly the rusts which often do much damage to the grain crops.

Air Movements.—Rains are brought to the land by air movements. It is known that large mass movements of air are of great significance in determining the type of climate found in a given area. Violent movements of air may result in storms, with resulting damage. Air movement from a dry area to one more humid may result in increased evapo-

ration and injury to the crop. It is not uncommon for dry southwest winds to move across the plains, raising the temperature as they go and desiccating the soil and plants to the point of injury.

Air movements are responsible for the transfer of pollen as in corn and rye. Without these movements, cross-pollination would not occur.

Temperatures vary widely according to the direction and rate of air movement. When a mass of cool air moves from the polar regions, temperatures fall. If there is little movement of air in the summer, temperatures tend to rise and remain rather uniformly high.

CROP ADAPTATION

A discussion of the factors of the environment naturally leads to the subject of crop adaptation. It seems best to explain crop adaptation in terms of the plant and its surroundings. Two terms are introduced as a basis for a better understanding of its meaning: the *hereditary rhythm* and the *environmental rhythm.*

Hereditary Rhythm.—The hereditary rhythm may be considered as the sequence of biological changes, of a particular species, from seed to seed. Thus, for a crop such as oats, the seed germinates when placed under favorable conditions of temperature, water, and aeration; the plant develops; flowers are formed; a seed is produced; and the cycle or rhythm is complete. While many species are much alike in their hereditary rhythm, there are numerous differences. For example, if spring wheat is planted in the fall of the year in a cold region, the plant will die while that of winter wheat will persist. Conversely, if winter wheat is planted in the spring of the year, the seed will germinate, a plant will develop, but it will fail to flower and reproduce. Why? Because its hereditary rhythm, based on its genetic complex, requires a period of low temperature to bring about flowering and reproduction. Thus, it is evident that, before the picture is complete, consideration must be given to the environmental sequence or the environmental rhythm.

Environmental Rhythm.—Any given section of the world has an environment which is peculiar to that area. Environmental factors vary widely, but in general a region has an average annual rainfall that is high, intermediate, or low: it has a long or a short growing season; it has fertile, average, or low fertility soil; it is subject to certain wind movements; it has much or little cloudy weather. In short, one could make a chart of the environmental factors of a region and determine its total possibilities and limitations for crop production. Each factor of the environment must be considered, as each plays its part. Blackman has

stated, "When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the slowest factor." The rate is not only limited but may be conditioned entirely by the factor. For example, in Minnesota the soil is favorable for cotton production, but the length of the growing season is too short to permit maturing the cotton crop. Regardless of how favorable a number of the factors may be, one alone may rule out the production of a species. Thus it is said that cotton is unadapted to Minnesota. Why? It is unadapted because the various factors of the environmental rhythm do not coincide with the hereditary rhythm of cotton. When all the factors of the hereditary rhythm coincide with the factors of the environmental rhythm, there is adaptation.

The sorghums are adapted to the southwest because their hereditary rhythm enables them to grow successfully in an environment that affords insufficient water for the successful production of corn.

The farmer groups a succession of crops in a rotation even though not all are best adapted. For example, on comparable soil, oats will yield more north of Iowa, but Iowa leads all other states in oat production. This is because oats are rotated with corn, a crop that is adapted to Iowa somewhat better than oats, but oats are well enough adapted to produce satisfactory crops.

Not so many years ago, Minnesota was not important as a corn state, but today it is one of the leaders. In part this is a result of the plant breeder modifying the hereditary rhythm of the corn plant so as to adjust it to the environmental rhythm. When a farmer applies fertilizer to his corn crop and causes it to mature a week earlier than would have been possible without the soil treatment, he has modified the environmental rhythm to more closely coincide with the hereditary rhythm.

Review Questions

1. In your own words describe the process of photosynthesis.
2. Why cannot animals manufacture food?
3. How does respiration differ from fermentation?
4. What is meant by anaerobic respiration?
5. Why is it important to germination to have soil in good tilth?
6. What is the effect of a heavy wet soil on newly planted grain?
7. What are trace elements?
8. Which elements come from the air? Which from the soil?
9. What is the cycle of plant growth?
10. Give the cycle of plant growth for corn. For oats.
11. What are the characteristics of a fertile soil?
12. What type of soil do you have on your home farm? How was it derived?
13. Why do crops tend to be earlier on sandy soils?

14. Explain why so many pounds of water are required to produce 1 lb. of dry matter.

15. What is a submarginal farm?

16. Explain the importance of the distribution of rainfall.

17. What is the average annual rainfall for your area?

18. What is meant by the length of the growing season?

19. Why is early planting desirable with the spring-sown grain crops?

20. How is light related to plant diseases?

21. How do air movements affect evaporation?

22. What is hereditary rhythm? Environmental rhythm?

23. Explain crop adaptation in your own words.

24. Explain why certain crops are limited to specific areas.

25. Give an example of a crop grown in a given region for economic reasons rather than because of best adaptation.

References

MEYER, BERNARD S., and DONALD B. ANDERSON: "Plant Physiology," D. Van Nostrand Company, Inc., New York, 1939.

ROBBINS, W. W.: "The Botany of Crop Plants," The Blakiston Company, Philadelphia, 1924.

SINNOTT, E. W.: "Botany: Principles and Problems," 3d ed., McGraw-Hill Book Company, Inc., New York, 1935.

"Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

CHAPTER II

PLANT CLASSIFICATION

Plants may be classified into groups on several different bases. The object of classification is to permit an orderly study of the various types and varieties. For example, the plant breeder makes valuable use of the details of the flower structure. When he emasculates the wheat flower, he knows that invariably he must remove three stamens from each floret. If one is left, then self-pollination may occur. It is important that he know the general characteristics of the grain crops in order that he may plan his improvement program along sound lines. The modern breeder knows the chromosome number of the crop with which he is working. Through the use of the microscope he is better able to predict the possible results of hybridization. The plant geographer who visits foreign countries looking for new plants must know something of plant characters if he is to evaluate properly new species that may be of economic value when introduced into a new region. A large percentage of the valuable crops and varieties grown in America are the result of such introductions.

SYSTEMATIC CLASSIFICATION

The scientist who classifies plants on the basis of their botanical characteristics is known as a *taxonomist* or *systematist*. The word taxonomy is derived from two Greek words: *taxis* (arrangement) and *nomos* (law). The agronomist is interested in the schemes of botanical classification since they are tools that, properly used, may be of aid in his program of work. No longer does the breeder proceed blindly and depend upon chance. Rather he studies the species and carefully plans his program, much the same as the chemist who combines certain known elements to produce a new compound. The better his understanding of the hereditary character of his breeding materials in their relation to plant performance, the more likely the plant breeder will be to succeed. Adequate knowledge of taxonomic characters may aid in the avoidance of numerous costly errors.

The Binomial System.—The binomial system includes the name of the *genus* (plural genera) and the *species*. Several definitions have been given for a species. Plants that are essentially alike in the majority of

their fundamental structural characters and that in reproduction, through a series of generations, produce offspring having the same fundamental characters as themselves may be designated as a species.

The genus, the other half of the name in the binomial system, may be considered as a group of species. It is a clearly defined concept including the essential characteristics common to all the related species, and is a broader grouping than the species. For example, the generic name of clover is *Trifolium*, referring to the fact that all true clovers as a rule have compound leaves of three leaflets. The species name frequently refers to a specific characteristic of the group, its habitat, its distribution, or it may bear the name of an individual who is being honored by the one naming the species. Examples are the following:

Trifolium repens (*repens* means creeping)
Triticum vulgare (*vulgare* means common; this is the species of the common wheats)
Hordeum distichon (*distichon* means two rows, name of two-rowed barley)
Avena nuda (*nuda* means naked, name of the hull-less oat)
Solanum nigrum (*nigrum* means black)
Convolvulus arvensis (*arvensis* means of the fields)
Cirsium iowense (*iowense* means Iowa)
Prunus besseyi (*besseyi* for Chas. Bessey)

THE GROUPING OF PLANTS

To understand the methods of grouping plants and to learn how to use the keys it is necessary that one become familiar with the terminology used, the system of keying, and the interrelationships of the various components of the key.

Not everyone should strive to become a systematist, but a trained agronomist should understand the tools of taxonomy so that he may use the various botanical classification keys with reasonable accuracy.

The following chart carries a variety of medium red clover through the entire scheme used in plant classification, ending with the variety, and illustrates the relationships between the various subdivisions.

Kingdom—Plantae—(plants)
  Division—Spermatophyta—(plants bearing seeds)
    Subdivision—Angiospermae—(seeds enclosed)
      Class—Dicotyledones—(seeds with two cotyledons)
        Subclass—Polypetalae—(corolla of separate petals)
          Order—Rosales—(carpels distinct—ovary simple)

Family—*Leguminoseae*—(fruit a legume)
Genus—*Trifolium*—(flowers in heads or umbels, leaves three-parted)
Species—*T. pratense*—(flowers red, hairy margined leaflets)
Variety—Cumberland—(disease resistant)

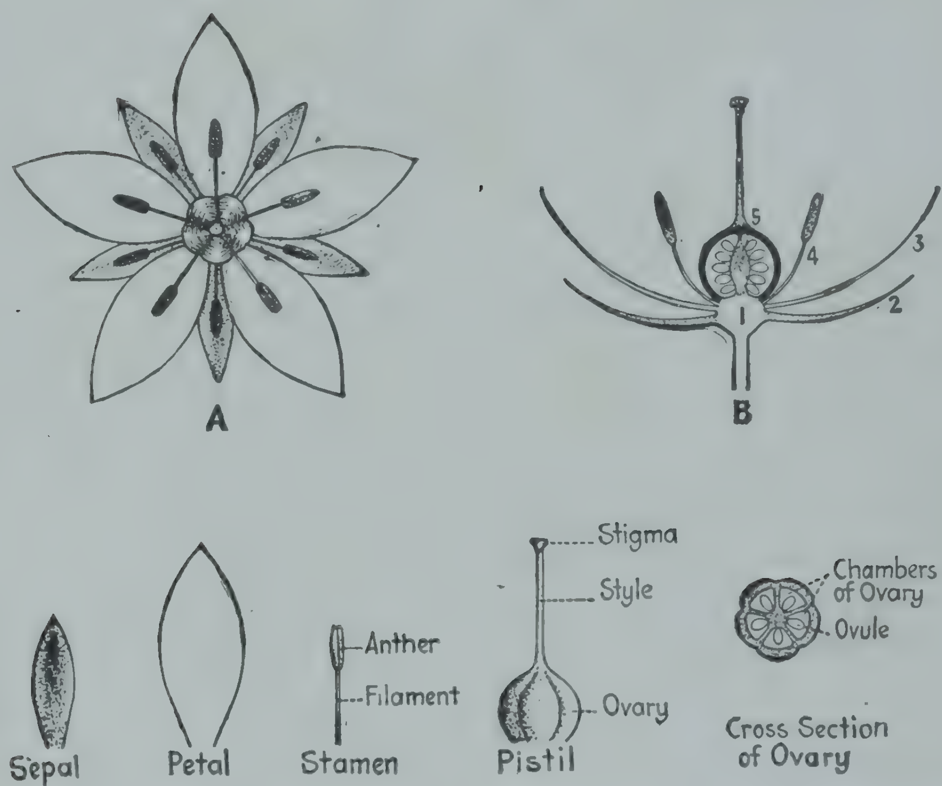


FIG. 4.—The structure of the flower of a dicotyledonous seed-plant (diagrammatic). *A*—face view of the flower, showing its calyx of five sepals, its corolla of five petals, its ten stamens, and its pistil. *B*—longitudinal section, showing the relations between the parts. (1) receptacle, (2) calyx, (3) corolla, (4) stamen, (5) pistil, with ovary cut lengthwise. (*After E. W. Sinnott.*)

Kingdom.—This is the first great major division of life, comprising the plant and animal kingdoms, which together include all living things. In most cases it is easy to differentiate between the two kingdoms and only in the lowest forms of life is there some doubt as to the proper grouping. The fungi and bacteria which are so important in diseases of grain crops are classified as minute plants.

Division.—The division is a subdivision of the kingdom. According to Sinnott[1] the divisions are (1) *Thallophyta*, (2) *Bryophyta*, and (3)

[1] SINNOTT, EDMUND W., "Botany: Principles and Problems," McGraw-Hill Book Company, Inc., 4th ed., New York, 1946.

Traceophyta. Some authors further subdivide the Traceophyta into *Pteridophytes* and *Spermatophytes*.

Thallophyta.—These are the simplest plants, their name coming from the word *thallus*, a simple cellular body lacking the stems and leaves found in higher plants, and the word *phyta*, which means plant. Thus the members in the group are thallus plants. Bacteria and the common algae as seen in stagnant water are representatives of this division.

The thallophytes are of great importance to agriculture since they include many plant diseases, chief among which are the smuts and the rusts. Not all members are harmful, some being very valuable, such as those important plants known as *yeasts*.

Bryophyta.—The bryophytes are chiefly moss plants somewhat more specialized and thus higher in the evolutionary scale than the thallophytes. They do not possess leaves or stems, so rank low in the plant divisions, having somewhat more complex sex characteristics than the thallophytes. The group is of little importance except as it serves to illustrate certain advances in evolution. None of the species is of economic importance.

Traceophyta.—This group includes the plants with vascular systems. The pteridophytes, of which the ferns are representative, have roots, stems and leaves, a great advance in evolution. The *spermatophyta* or seed-bearing plants include the plants with which we are most familiar. The principal evolutionary advance was the development of the seed, which is so highly important, not only for the perpetuation of the species but as a source of much of the food of the world.

Subdivision.—This represents a grouping of the seed-bearing plants into the two groups: (1) *gymnosperms* and (2) *angiosperms*. The angiosperms have their seeds enclosed, while those of the gymnosperms are naked. In the evolutionary scale the gymnosperms were the first seed-bearing plants. The earliest types of gymnosperms had their seeds exposed to the air, while in the angiosperms the seeds are enclosed within a structure commonly referred to as the *ovary*. The change from naked seed to enclosed seed is considered to be an advance in evolution, so that angiosperms are considered more advanced than gymnosperms.

Gymnosperms.—As indicated, the seeds are not enclosed within an ovary. Many of the species are of little or no economic importance. Economic plants include the evergreens, such as the pines, firs, cedars, spruces, and hemlocks, many of which are of great value to mankind.

Angiosperms.—All the grain crops are included in this grouping. In every case the seed is produced within an ovary. All the fruit crops

are angiosperms since they have enclosed seeds. It is with the angiosperms that agriculture is primarily concerned, as nearly all cultivated plants fall within this classification.

Class.—The two divisions of the class are *monocotyledoneae* and *dicotyledoneae*. As the names imply, the former has plants with one cotyledon in the seed while the latter has two cotyledons. Most of the grain crops are monocotyledonous; flax and buckwheat are dicotyledonous.

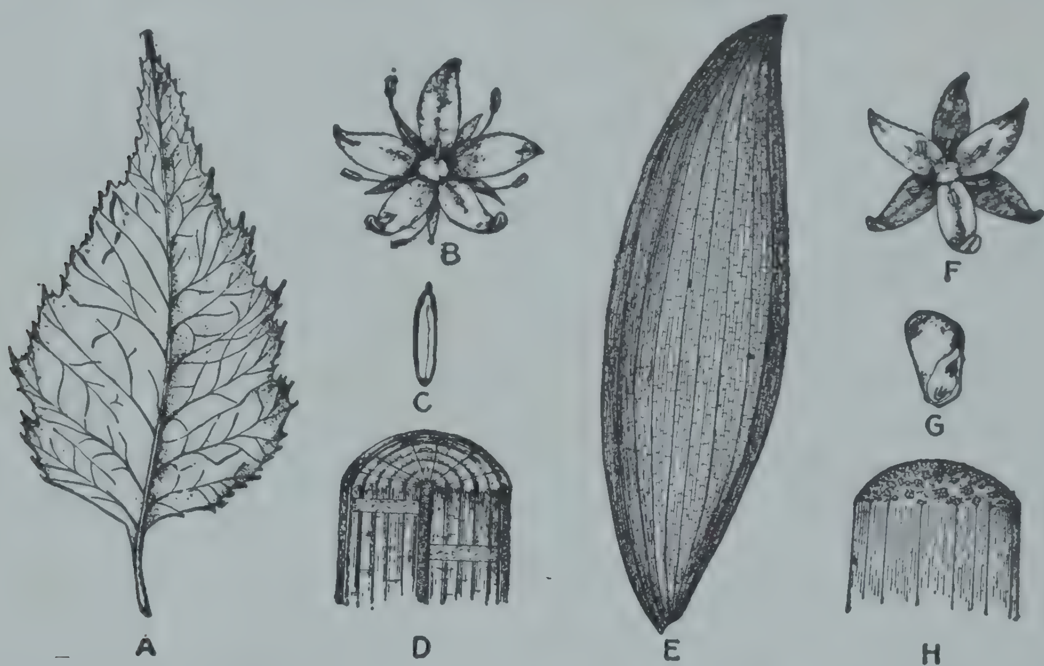


Fig. 5.—Characteristics of a typical dicotyledonous plant (*left*). *A*, netted veined leaf. *B*, flower on the plan of five. *C*, two cotyledons in the seed. *D*, the vascular cylinder of the stem a solid ring. Characteristics of a typical monocotyledonous plant (*right*). *E*, parallel-veined leaf. *F*, flower on the plan of three. *G*, single cotyledon in the seed. *H*, vascular bundles scattered in the stem. (*After E. W. Sinnott.*)

Monocotyledons.—The stems of monocotyledons have no central pith or annual rings. The fibrovascular bundles are distributed through the stem, as is readily observed in the cornstalk. The embryo possesses a single cotyledon or, as it is sometimes called, a seed leaf. The flower parts generally are found in threes or sixes, never in fives, and usually the leaves are parallel-veined. Corn, sorghums, oats, wheat, barley, rye, and rice are all monocotyledonous plants.

Dicotyledons.—The dicots, as they are commonly called, have many more genera than the monocots, but include few of the grain plants. They are characterized by woody stems having a bark and pith and in the perennials the annual addition of a layer of growth. The embryo, as previously stated, has two cotyledons. The leaves are net-veined, and the parts of the flowers occur in fours or fives. It is believed that

the dicots are much older in the evolutionary scale than the monocots. This grouping includes the great legume family with its many important agricultural crops.

Subclass.—In the subclass are two groupings: (1) corolla absent and (2) corolla present.

Corolla Absent.—No petals are found in the species included, and the calyx may or may not be present. This group includes some of our bad weeds and many important species of valuable trees, of which the elm, walnut, and hickory are representatives.

Corolla Present.—Here both the corolla and the calyx are present. This grouping includes the legumes, apples, pears, peaches, cotton, and many other important species. The parts of the corolla are separate, as indicated in the outline.

Order.—The order is a further subdivision which makes up a group of families. The order is similar to the family, and some investigators use the two terms more or less synonymously. The names of orders usually end in *-ales*. The order Rosales includes many of our important fruits and the legume family. Since the order is a grouping of families, there is no grouping of equal value as has been true in the parts of the classification discussed so far.

Family.—As stated before, the family is much like the order except that families are grouped into orders. For example, Gray[1] lists seven families of the central and northeastern United States and Canada in the order Rosales. The names of families usually end in *-acea*, but an important exception is the grass family, *Gramineae*.

Agriculturists frequently speak of the grass (*Gramineae*) family, the legume (*Leguminoseae*) or the flax (*Linaceae*) family, and several others of lesser importance. The Gramineae family, which includes many of our important agricultural crops, includes some 312 species native to central and northeastern United States and adjacent Canada.

Genus.—The word genus has been defined, but to carry out the key its relationships will be expanded. This is a working division and is the one most commonly used in referring to plants. The leaves of the clover plant are trifoliate with stipules united with the petiole, and the flowers occur in heads or spikes. Thus we have a grouping known as the genus *Trifolium.*

Species.—The species is the common ultimate division in the botanical classification of plants and is in effect a subgroup of the genus. *Trifolium pratense* and *T. medium* are very much alike in appearance as

[1] Robinson, Benjamin L., and Merritt L. Fernald, "Gray's New Manual of Botany," 7th ed., American Book Company, New York, 1908.

both have oval-shaped flower heads with reddish to purple corollas (rarely white). A careful examination of the flowers shows that *T. pratense* has soft hairs on the calyx, while that of *T. medium* is nearly free from hairs. The taxonomist groups both in the genus Trifolium but because of the small differences subdivides them further into species.

Variety.—Here is a subdivision of the species designed to designate a plant that differs in certain characters. It does not differ sufficiently from other members of the species to warrant giving it a separate species name. Often the differences are not morphological and are not readily distinguished by observation. Accordingly, such a subgroup may be referred to as a *variety*. For example, a recently developed red clover variety has been named Cumberland. In appearance it resembles other red clovers, but it is classed as a separate variety because of its disease resistance.

In some cases the term *strain* has been used to indicate small but often important differences from the original variety. This term is commonly used in reference to open-pollinated corn varieties to designate certain strains that differ slightly from the original variety.

CLASSIFICATION ON BASIS OF GROWTH HABIT

This classification relates to the life of the plant and its response to its environment. The usual groupings include (1) annuals, (2) biennials, and (3) perennials.

Annuals.—These are plants that complete their cycle of growth within one crop season, *i.e.*, they are planted in the spring or summer and normally complete their growth before cold weather. Many of our important grain crops are annuals, including such crops as spring-sown oats, wheat, barley, flax, corn, and soybeans. Those crops which start their growth in the late summer or fall, pass through the winter in a dormant state, and complete their cycle of growth the following year are known as *winter annuals*. Examples are winter types of rye, oats, and barley. In regions where the winters are very mild, typical spring varieties may be grown as winter annuals.

Biennials.—These species require two seasons to complete their growth, starting growth one year, becoming dormant during the winter, resuming growth and flowering in the second season. None of the grain crops comes within this classification.

Perennials.—Under favorable conditions these plants live three or more years and may or may not produce seed each year. None of the grain crops falls within this grouping.

AGRONOMIC CLASSIFICATION

The agronomist classifies the various crops according to their uses. Several schemes are followed, with each having its own special application.

On the basis of use to be made of the crop, there are cash crops and feed crops. The cash crops are grown primarily for marketing and may include any or all of the grain crops. Wheat, flax, corn, soybeans, and rice, in particular, are grown as cash crops, although they may be used for feed. Many farmers use these crops interchangeably according to market conditions and demands. Thus corn is an ideal feed crop as well as a cash crop, while flax and rice are rarely used as feed crops. As indicated, feed crops are those fed directly to livestock. Wherever livestock are fed there is great demand for feed crops. In the corn belt the principal hog-fattening areas correspond rather closely with the corn-growing sections.

Several other terms are used to classify crops, based upon their characteristics and uses.

Small Grains.—This term is used to distinguish the small-seeded crops such as wheat, oats, barley, and flax. Small grains are very nearly synonymous with *cereal crops*, except that usually the term cereal is restricted to those crops which are members of the grass family. The small grains also do not include corn, which is classed as a cereal and because of its seed size is not referred to as a small grain. Of the grains, the grain sorghums are raised for their seed, while the sweet sorghums are grown principally for forage or plant parts. Within the scope of this text, soybeans grown for their seed are considered as grain crops.

Special Classes.—The term *nurse crop* is widely used for a companion crop. No crop really serves as a nurse crop; each is in competition with the other. When oats and clover are grown together, it is best to refer to the oats as a companion crop rather than a nurse crop.

Emergency crops are those seeded during an emergency. For example, during dry years when feed is scarce farmers may seed proso millet to secure emergency grain. When a wet, cold season delays corn planting it may be necessary to plant a quick-growing emergency crop such as buckwheat.

Cover crops include plantings that are made primarily to serve as a cover for the soil. In many cases they are used for other purposes as well, such as for pasture or for green manure. The use of buckwheat in an orchard is a good example of a grain crop used for cover.

Fiber crops are those grown for their fiber. Of the grains considered here, only flax is used as a fiber crop, although both grain straw and

cornstalks may be employed in the manufacture of paper and related products.

Review Questions

1. Give as many reasons as possible why it is worth while to understand the principles of plant classification.
2. What is meant by the binomial system?
3. Give the advantages of the binomial system.
4. Why do we say that in plant classification we have a universal language?
5. What is the meaning of the word *phyto?*
6. Why are the thallophytes of such great interest to the plant scientist?
7. What are cotyledons?
8. Why is it necessary to prepare a better seedbed for a dicotyledonous than a monocotyledonous species?
9. List several important spermatophytes.
10. What gymnosperms grow in your area?
11. How can one differentiate between a monocot and a dicot?
12. What are annual rings?
13. Name the families of plants of greatest economic importance to the farmer.
14. What is the corolla?
15. What is the probable function of bright colors in flowers?
16. How would a knowledge of plant classification aid the plant breeder? The plant geographer?

References

HAYWARD, HERMAN E.: "The Structure of Economic Plants," The MacMillan Company, New York, 1938.

RATHER, HOWARD C.: "Field Crops," McGraw-Hill Book Company, Inc., New York, 1939.

CHAPTER III

DISTRIBUTION OF GRAIN CROPS

Grain crops, like all other plants, tend to group themselves in certain rather definite regions. Man has modified this distribution greatly as he has tested species in new areas and has created varieties better adapted to specific regions than would have been possible without his efforts.

It is of interest to become familiar with the grain-producing areas of all parts of the world. With the greater increase in world commerce, one can expect even more influence on local grain prices as a result of crop production in every region. For years the price of wheat in America has been based on the world situation. In general, other grain crops tend to follow the lead of wheat. It is not enough to know how to produce the crop; there remains the important problem of marketing. A consideration of the important grain-producing areas of the world and of the United States should aid in an understanding of the economic problems related to the orderly marketing of grains.

PRINCIPAL GRAIN AREAS OF THE WORLD

The important grain-producing sections of the world possess many of the environmental characteristics pertinent to the high producing regions of the United States. Although the impact of war disrupts production, it is possible to consider these areas as they were in peacetimes when it is more likely that production approached normality. For this reason production figures will be given in part for the prewar period, although many war period data are given.

Wheat.—As a leading food crop of the world, wheat is of great interest, and certain rather well-defined areas are important in its production. The United States, the Union of Soviet Socialist Republics, and China are the chief wheat-producing countries of the world, and in general the soil and climatic conditions of each are fairly similar. Since wheat is used primarily for human food it tends to command the use of the better soils.

From the data in Table 1, the student may readily see which countries are the greatest competitors in the wheat markets of the world. Countries in the Western Hemisphere such as Canada and Argentina tend to come more directly in competition with the United States than

the other wheat-producing areas. Both countries produce much more wheat than is needed for their own consumption and usually have large quantities for export.

TABLE 1.—PRINCIPAL WHEAT COUNTRIES OF THE WORLD, PRODUCTION IN BUSHELS*
(1941–1944 average, unless otherwise indicated)

United States	959,243,000
Union of Soviet Socialist Republics	860,448,000†
China	820,624,000‡
Canada	397,876,000
India	370,660,000‡
Italy	245,103,000
France	229,646,000
Argentina	218,367,000
Germany	170,212,000†
Australia and New Zealand	129,340,500
Estimated world total	3,786,000,000§

* Adapted from United States Department of Agriculture, *Agricultural Statistics.* Other production data in this chapter are from the same source.

† 1930–1934 average.

‡ 1935–1939 average.

§ 41 countries, not including the Soviet Union, represent about 95 per cent of estimated world total.

Rye.—Like wheat, rye is an important food, especially in the European and Asiatic countries. Its greater hardiness and ability to grow on lighter soils make it a surer crop than wheat in many of these countries. In America, relatively little rye is used for human consumption, the bulk of the crop being used for livestock feed and for alcoholic distillation.

TABLE 2.—PRINCIPAL RYE COUNTRIES OF THE WORLD, PRODUCTION IN BUSHELS
(1941–1944 average except as indicated)

Union of Soviet Socialist Republics	829,024,000*
Central Europe (Germany, Austria, Czechoslovakia, Poland, and Luxembourg)	655,629,000†
Balkans	62,314,000†
United States	39,840,250†
France	30,013,000†
Estimated world total	1,530,000,000

* 1930–1934 average.

† 1935–1939 average.

Because of its limitations rye usually does not sell as well as wheat. In the United States the price of rye is generally low in comparison with that of wheat since it must compete as a feed and not as a food. In areas where wheat is not adapted, as on sandy soils, rye may prove the far more profitable crop.

Oats.—For years oats have been referred to as an outstanding feed for horses, but with the increased use of the tractor there has been a corresponding decrease in the horse population. The oat crop is used primarily for feed, with a limited quantity entering into human food products. The quantity used for food is too small to affect the general market prices. However, in many years oats suitable for the milling trade command a premium over feed oats.

TABLE 3.—PRINCIPAL OAT COUNTRIES OF THE WORLD, PRODUCTION IN BUSHELS
(1941–1944 average except as indicated)

United States	1,208,526,500
Union of Soviet Socialist Republics	936,735,000*
Germany	405,338,000†
Canada	484,785,000
France	329,299,000†
United Kingdom	224,192,500
Czechoslovakia	86,515,000†
Denmark	69,697,000†
Sweden	56,386,250
Argentina	52,591,750
Estimated world total	4,258,750,000

* 1930–1934 average.
† 1935–1939 average.

Here the United States ranks first in production. The oat crop is popular with American farmers because of its sureness as a crop, its suitability in the rotation, and its all-round usefulness as a feed crop. The high quality of the straw likewise adds to the general popularity of oats.

Barley.—Like oats, barley is an important feed crop wherever it is grown, being superior to oats in feeding value, Considerable barley is used in the malt industry, both for specialized food products and the production of beer. On the American markets it is common to speak of feed barley and malting barley according to the usage to be made in each case. The barley crop is not so popular with farmers as oats since it is much more likely to yield poorly when environmental conditions are not favorable. Certain diseases of barley are not so easily controlled as those of oats, and farmers are less confident of producing a barley crop than oats; except under favorable conditions farmers usually do not obtain such good returns from barley as from oats. For these reasons, barley production tends to be somewhat more specialized than oat production.

It is interesting to note that China ranks first in barley production. Much of the barley produced in China is used for human food. In spite of the great production, China with her large population was not an

TABLE 4.—PRINCIPAL BARLEY COUNTRIES OF THE WORLD, PRODUCTION IN BUSHELS
(1941–1944 average except as indicated)

United States	440,476,700
China	361,150,000*
Central Europe	280,956,000
Union of Soviet Socialist Republics	270,674,000*
Canada	194,999,000
India	103,619,000†
Japan	73,149,000†
Spain	71,720,750
French Morocco	46,955,500
Estimated world total	2,322,500,000

* 1930–1934 average.
† 1935–1939 average.

important factor in world grain trade. Most of the leading barley-producing countries are heavily populated and require the greater share of the barley produced for home consumption.

Flax.—The Second World War brought to America as never before her need for home-produced oils. The flax plant has played an important part in this respect, since the quality of the oil is such that the soybean, our leading oil-producing crop, cannot compete with it on a quality basis. Relatively little flax is used for feed, nearly all the seed being crushed for its oil. The by-product from the crushing, linseed meal, provides valuable feed, which is highly prized by the livestock industry.

TABLE 5.—PRINCIPAL FLAXSEED COUNTRIES OF THE WORLD, PRODUCTION IN BUSHELS
(1941–1944 average except as indicated)

Argentina	52,246,500
United States	37,203,000
Union of Soviet Socialist Republics	29,865,000*
India	16,150,000
Estimated world total	159,775,000

* 1930–1934 average.

Argentina is the principal competitor of the United States in the sale of flaxseed. Because of the cheapness of water transportation,

Argentina is able to ship flax to crushers located in our Eastern coastal cities at a cost below that required to transport the flax by rail from the Middle West to these same markets. Much of the flax is processed in Minnesota and the oil shipped from there to other points. For years a high tariff has been used to maintain the prices paid to American farmers for the flax produced.

Other Small Grains.—Rice, buckwheat, and the millets are other small grains of some importance in the Untited States. None is grown so extensively in America as those previously listed, but production data on all crops are given in the government statistical bulletin referred to in Table 1.

TABLE 6.—PRINCIPAL RICE COUNTRIES OF THE WORLD, PRODUCTION IN BUSHELS
(1941–1942 to 1944–1945 average except as indicated)

China	2,623,383,000*
India	2,019,123,500
Japan proper	529,894,000*
Burma	348,534,000*
French Indo-China	281,497,000†
Estimated world total	7,432,000,000*

* 1935–1936 to 1939–1940 average.
† 1930–1931 to 1934–1935 average.

As is evident from Table 6, rice is a most important crop. Undoubtedly more human beings depend upon rice as their principal article of food than is true for any other crop. Although the crop is grown to but a limited extent in the United States, the student of agronomy should be familiar with the general importance of rice and its part in world economy. With the increased commerce with all sections of the world, it is to be expected that the importance of the rice crop in other parts of the world will tend to exert more and more influence upon the agriculture of America.

Corn.—As the United States produces more than one-half of the total world production, it is evident that corn is the leading American crop. The plant, which is native to this hemisphere, has had its greatest improvement and use in America, where the word corn comes close to being a synonym for agriculture. The great production of corn has led to many surpluses with vexing problems of utilization. Argentina has been one of America's leading competitors in the world's markets in the sale of corn as well as several other agricultural products. Much corn is utilized on the farm for feed, and the area of most concentrated production coincides with the area of greatest hog production. As a

feed for fattening livestock, corn has few equals. The farmer has learned that it is an economical and usually profitable process to market his corn in animal products. Many countries are important producers of this very useful agricultural crop.

While corn is used primarily for feeding to livestock, considerable quantities are used for human food. In the United States the amount used for human food probably is not more than 10 per cent. In some countries, as in Mexico, a much greater percentage of corn is consumed

Table 7.—Principal Corn Countries of the World, Production in Bushels
(1941–1944 average except as indicated)

United States	3,017,505,750
China	310,000,000
Argentina	223,143,000
Brazil	214,813,000*
Rumania	211,890,000*
Yugoslavia	175,945,000*
Italy	113,881,000*
Hungary	92,006,000*
Mexico	85,581,250
Egypt	55,801,250
Estimated world total	5,276,250,000

* 1935–1939 average.

as human food. Those countries which do not have available wheat or rice tend to consume relatively greater percentages of corn. In the United States most of the corn is fed as grain, with a considerable percentage being used as a forage either as fodder or silage.

Grain Sorghums.—As indicated in an earlier chapter the grain sorghums are most widely grown in areas where corn is not successful. Where corn is adapted it will usually yield more feed than the grain sorghums. In some countries, as in China, the grain sorghums are used for human food. In America they are grown as feed for livestock. The grain sorghums, such as kafir, approach, but are not quite equal to, corn in feeding value. The grain-producing types are not of sufficient significance as world crops to warrant the presentation of production figures. The production in the United States will be discussed in a later chapter.

GRAIN PRODUCTION IN THE UNITED STATES

Having surveyed the world picture of grain production it is logical to consider the same crops in their areas of importance within the United States. Although man may be responsible for some shifts in crop-producing areas, in general a given crop is grown in those states where

it is best adapted. In a survey of the individual states it seems desirable to consider a somewhat later period than was given for the world picture. The data presented are for the 10-year period previous to the Second World War.

Wheat.—In the discussion of world production, all types of wheat were considered together. In the United States it seems advisable to group the different types of wheat because of their specific uses and importance in the agriculture economy of America.

TABLE 8.—PRINCIPAL WINTER WHEAT STATES, PRODUCTION IN BUSHELS

State	1933–1942	1944
Kansas	125,965,000	191,624,000
Oklahoma	48,419,000	85,914,000
Ohio	41,934,000	46,805,000
Nebraska	39,360,000	35,009,000
Illinois	34,144,000	24,472,000
Washington	28,954,000	40,270,000
Texas	28,195,000	74,746,000
Indiana	28,047,000	26,380,000
Missouri	26,851,000	23,800,000
Pennsylvania	18,400,000	20,108,000
United States total	570,675,000	764,073,000

The state of Kansas has long been the leading wheat-producing state. The climate and soils of this section of the country are well suited to the production of high-quality wheat. Here the wheat is primarily hard red winter, a class of wheat especially suited to the making of superior quality flour. The relatively low but ample rainfall, together with fertile soils, results in wheat that is high in protein and of outstanding characteristics. The general region embraces several states, of which Kansas, Oklahoma, Nebraska, and Texas are leaders in total production.

To the east of the hard red winter wheat belt are found the soft red winter wheats. These wheats, as the names implies, are softer in texture and generally are not so high in protein. They are used in the making of soft wheat flours and in blending with the flours from the harder wheats. In Missouri, for example, there is an overlapping between the hard and the soft red winter wheats. In the states to the east most of the wheat is of the soft red winter class.

In a more limited area are found the states producing the hard red

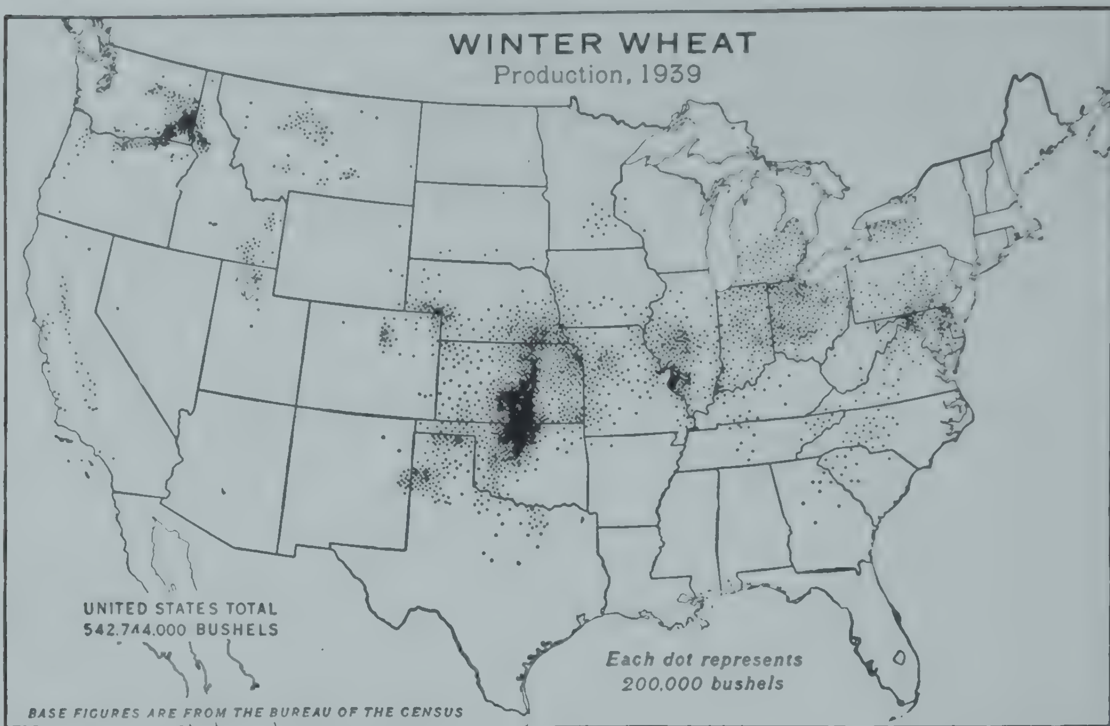


FIG. 6.—The acreage of hard red winter wheat is about twice as large as that of the other two winter wheat areas combined. The hard red winter varieties are grown principally in the central and southern Great Plains areas. The soft red winter types are found chiefly in the eastern half of the United States and to some extent in the Pacific Northwest. The white wheats are grown in the Far Western States and in New York, Michigan, and Ohio. (*Courtesy of the U.S. Department of Agriculture.*)

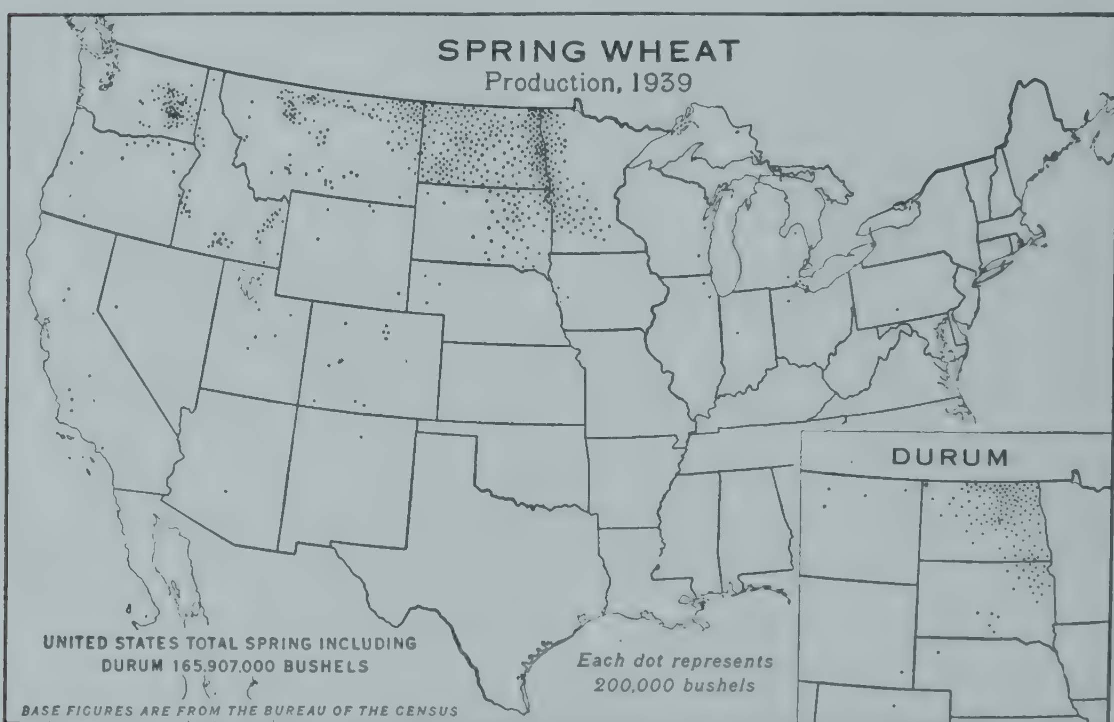


FIG. 7.—In 1939, spring wheat including durum wheat, represented more than 25 per cent of the wheat produced in this country. Most spring wheat is grown in the Northern Plains and prairie states. (*Courtesy of the U.S. Department of Agriculture.*)

spring wheats. As the name of the class suggests, these wheats are planted in the spring of the year and mature within the summer months. With spring-sown grains, hot summer temperatures are more serious than with winter wheats. For this reason the spring wheats are mostly grown in the more northern states where mean temperatures are lower.

TABLE 9.—PRINCIPAL SPRING WHEAT STATES, PRODUCTION IN BUSHELS

State	1933–1942	1944
North Dakota	53,560,000	132,660,000
Montana	26,766,000	48,078,000
Washington	19,243,000	23,760,000
Minnesota	19,162,000	18,088,000
South Dakota	14,980,000	34,502,000
Idaho	10,332,000	12,529,000
Oregon	5,970,000	4,255,000
Colorado	3,657,000	2,310,000
Utah	2,081,000	2,278,000
Nebraska	1,725,000	935,000
United States total	162,112,000	282,641,000

The production figures for spring wheat include all spring-sown wheat except the durum varieties. In Table 9 are included both hard red spring wheats and all white wheats that are seeded in the spring.

The hard red spring wheat varieties are much like those of hard red winter, and in general the flour is used for breadmaking purposes.

The durum wheat varieties are not grown extensively in the United States, and only three states are important in their production. In one of these states, North Dakota, durum is a very important class of wheat.

TABLE 10.—PRINCIPAL DURUM WHEAT STATES, PRODUCTION IN BUSHELS

(1933–1942 average)

North Dakota	22,260,000
South Dakota	4,039,000
Minnesota	1,114,000
Total for three states	27,413,000

The white wheats are usually soft and are unsuited for the making of bread flour. Most of the white wheats enter into the making of cracker or pastry flours or for blending with stronger wheats. Most of the white wheat is grown on the Pacific Coast and adjacent states and in northeastern United States. It should be remembered that white wheat varieties are found in both the winter and spring types.

It is evident that the durum wheat area coincides rather closely with the hard red spring wheat section except that the production of the durums is rather well limited to 3 states. The durum wheats are used primarily for the manufacture of macaroni and related products. The market for this type of wheat is limited; therefore the durum wheats are not generally so popular with farmers as the hard spring wheats. However, in many years there is a very good demand for durum wheat, and the farmer who produces high-quality grain often finds the crop very profitable.

Rye.—Rye is secondary to wheat, being grown for the most part where conditions are unfavorable for wheat production. In the United States rye may be grown as a pasture crop or as a combination pasture

Table 11.—Principal Rye States, Production in Bushels

State	1933–1942	1944
North Dakota	8,302,000	2,016,000
South Dakota	6,305,000	4,508,000
Minnesota	5,322,000	1,221,000
Nebraska	3,486,000	3,444,000
Wisconsin	2,648,000	1,000,000
Indiana	1,661,000	1,080,000
Michigan	1,468,000	949,000
Iowa	1,193,000	150,000
Pennsylvania	1,100,000	735,000
Illinois	1,016,000	759,000
United States total	40,446,000	25,872,000

and grain crop. In the latter case, the plants are grazed in the fall or spring or both and then permitted to head and mature grain. Most varieties are fall sown, although some spring types are available. It is common in many of the leading rye-producing states to seed rye on the lighter, sandy soils where it generally produces more grain than the other small-grain crops.

While rye bread is a tasty product, it is not eaten extensively in America. Much of the so-called rye bread is a blend of rye and wheat flour since the straight rye flour produces a bread that is not relished by many. The price of the grain is largely dependent upon its use as feed. As a feedstuff it is not popular since it lacks palatability and tends to form a sticky mass in the animal's mouth.

Oats.—In the United States, oats are grown both as a spring-sown

and as a fall-sown crop, but far the greater percentage of the crop is spring sown. As a rule the farm price of oats is low in comparison with other grains. It is frequently stated that the oat crop is grown at a loss; still many farmers continue to grow oats. The ease with which the crop is grown and the many uses that may be made of the grain and straw influence many farmers. The high-quality straw may be used as a roughage feed under certain conditions, and it is extremely valuable for livestock bedding.

As was stated in the discussion of crop adaptation, Iowa leads in oat production largely because the oat serves so well in rotation with corn.

TABLE 12.—PRINCIPAL OAT STATES, PRODUCTION IN BUSHELS

State	1933–1942	1944
Iowa	178,708,000	144,270,000
Minnesota	135,359,000	155,960,000
Illinois	115,311,000	101,984,000
Wisconsin	76,610,000	118,938,000
Michigan	43,549,000	44,100,000
South Dakota	40,764,000	92,430,000
Missouri	40,710,000	29,970,000
Ohio	40,351,000	37,224,000
Indiana	38,976,000	31,400,000
Nebraska	37,248,000	35,586,000
Kansas	35,931,000	28,098,000
North Dakota	35,220,000	82,041,000
Texas	33,213,000	38,600,000
United States total	1,028,280,000	1,166,392,000

Most of the important oat-producing states are leaders in corn production. Since the advent of the soybean, it has tended to replace oats to a certain extent.

The oat is not so important in world commerce as wheat or corn. There is less tendency to ship oats as far, since they are rather bulky. The food processor demands a high-quality product and frequently must ship the grain a considerable distance because so many oat fields are badly mixed with other grains, particularly barley. A large percentage of the oats produced is fed to livestock on the farm and does not enter into trade as grain.

Barley.—Usually the barley crop is more specialized than oats. While it fits into the same place as oats in the rotation, farmers generally

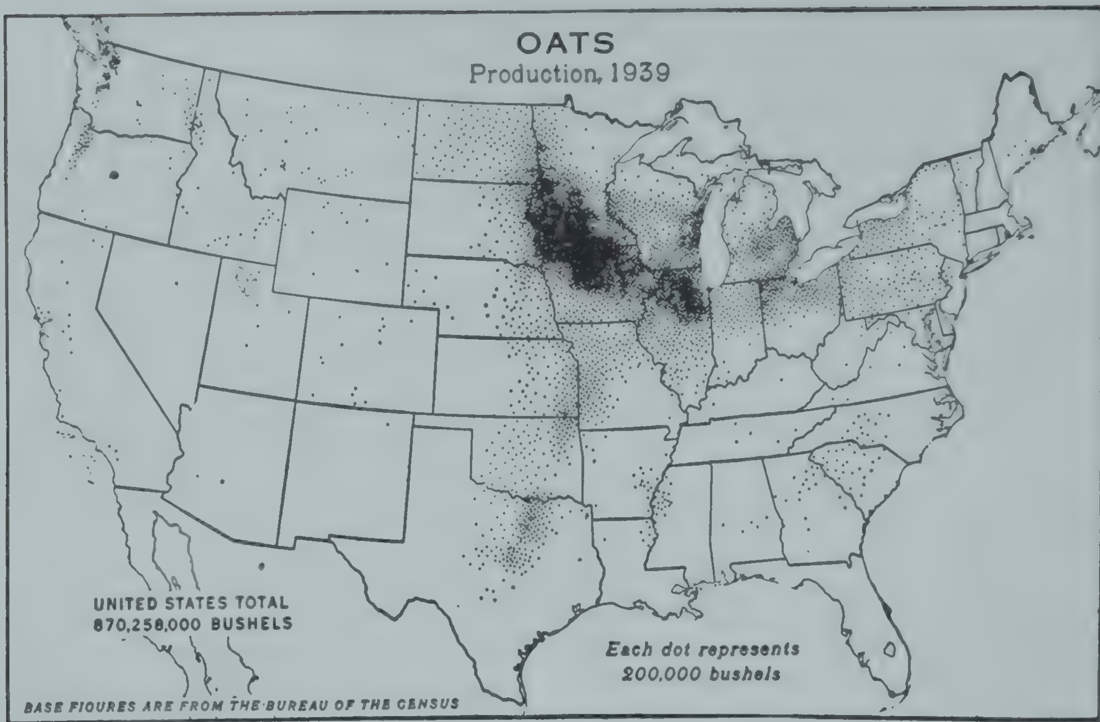


FIG. 8.—Oat production in 1939 was below average as indicated in Table 12. A considerable acreage of oats has been replaced by the soybean, principally in the corn belt. (*Courtesy of the U.S. Department of Agriculture.*)

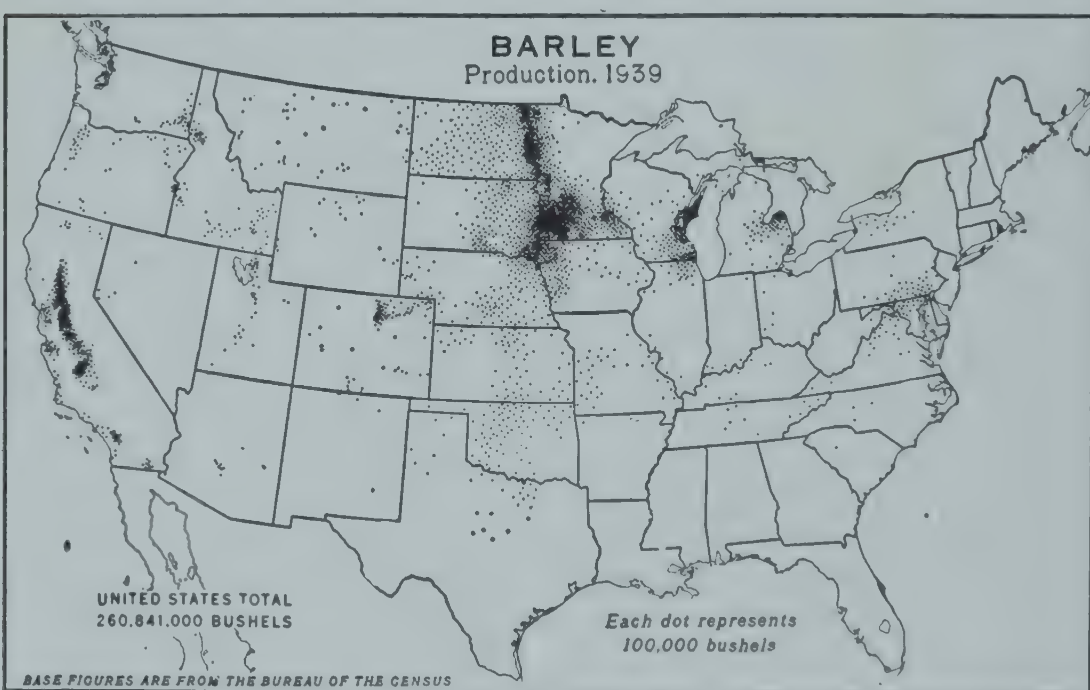


FIG. 9.—The United States produces about 10 per cent of the world's barley. More than half of the crop is grown in the North Central states. (*Courtesy of the U.S. Department of Agriculture.*)

do not grow barley except to produce a feed or cash crop. The malting types of barley are grown primarily for sale to the malster, and when a good crop is produced it usually proves to be highly profitable. As a feed, barley is somewhat superior to oats since it contains only about one-half as much hull. In the cooler areas of the north where corn cannot be matured, barley affords an excellent substitute. Much barley, particularly from the Pacific Coast, enters into world trade. The barley produced in the Middle West is used for feed or is processed by near-by malting companies. A later discussion will bring out the fundamental differences between the two major types of barley.

TABLE 13.—PRINCIPAL BARLEY STATES, PRODUCTION IN BUSHELS

State	1933–1942	1944
Minnesota	44,911,000	13,884,000
California	31,734,000	40,012,000
North Dakota	28,443,000	59,062,000
South Dakota	25,164,000	28,448,000
Wisconsin	20,372,000	5,062,000
Nebraska	18,207,000	8,928,000
Iowa	9,844,000	259,000
Colorado	9,620,000	14,986,000
Kansas	8,980,000	14,348,000
Idaho	6,627,000	12,728,000
Michigan	5,235,000	3,900,000
United States total	256,350,000	284,426,000

As with oats, there are winter and spring varieties of barley. The winter types are of relatively little importance when considered in relation to the large production of spring types.

Flax.—Only a few states produce flax as a grain crop. In most areas the crop is spring sown and competes with other spring grains for a place in the rotation. Most of the grain is crushed for its oil, either at plants located in the Middle West or on the Atlantic Coast. The seed prices are affected by world conditions and the ability of competitors to offer flax at a low price. Since the plant does not compete well with weeds, farmers will not grow the crop unless assured of a fair price. For years the price of flax has been supported by a relatively high tariff, but even with this subsidy it has been difficult to stimulate enough production to care for the needs of the processors.

TABLE 14.—PRINCIPAL FLAXSEED STATES, PRODUCTION IN BUSHELS

State	1933–1942	1944
Minnesota	8,642,000	6,514,000
North Dakota	3,078,000	7,661,000
California	1,565,000	2,788,000
Iowa	1,153,000	656,000
South Dakota	1,109,000	2,799,000
Kansas	673,000	452,000
Montana	524,000	1,453,000
United States total	17,180,000	23,527,000

For years most of the grain flax has been grown in Minnesota and the Dakotas. Recently California has greatly increased its production and has become an important flax-producing state, producing 2,788,000 bu. of flax in 1944.

Rice.—Relatively little rice is grown in the United States. For the period 1933–1942, Louisiana, Texas, Arkansas, and California, in the order given, produced a little more than 49,000,000 bu. of rough rice, the total production in the United States. It is interesting to note that in normal times we export some rice, primarily to Alaska, Hawaii, and Puerto Rico.

Buckwheat.—While buckwheat is grown in many states it is not a major crop, with the possible exception of Pennsylvania and New York, which produced 2,423,000 and 2,333,000 bu., respectively, as an average for the period 1933–1942. Since the total average production in the United States for the same period was 7,020,000 bu. it is evident that the two states were responsible for more than one-half of the buckwheat produced. Much of the buckwheat is processed locally and does not enter into trade. In normal times the United States exports about 300,000 to 400,000 bu. annually.

Corn.—The leading American crop plays a most significant part in the nation's agriculture. Where corn yields well, usually the farmers are prosperous and agriculture is on a high level. The states leading in corn production are known as the corn belt, although considerable corn is produced in every state of the Union. The production of hybrid varieties has been a stimulus to production and has led to some shifts in the corn belt. It seems appropriate that the changes brought about by hybrid corn be evidenced. In Table 15 not only the 10-year average but also the 1942 figures are given to illustrate more clearly the effects of the increased use of hybrid varieties.

TABLE 15.—PRINCIPAL CORN STATES, PRODUCTION IN BUSHELS

State	1933–1942	1944
Iowa	421,769,000	607,608,000
Illinois	330,989,000	403,695,000
Indiana	164,777,000	176,244,000
Minnesota	155,934,000	253,399,000
Ohio	147,230,000	142,956,000
Nebraska	116,838,000	329,855,000
Missouri	102,573,000	162,554,000
Wisconsin	82,275,000	116,536,000
Texas	75,569,000	69,622,000
Kentucky	65,808,000	67,080,000
United States total	2,369,384,000	3,228,361,000

It is rather evident that the average corn production for the coming few years is likely to be greater than the averages given in the table. Some states, particularly in the heart of the corn belt, have increased soybean production and decreased corn acreages. These shifts in crops exert a marked influence, but the most notable effect has been the nearly universal adoption of hybrid varieties in the principal corn-producing states.

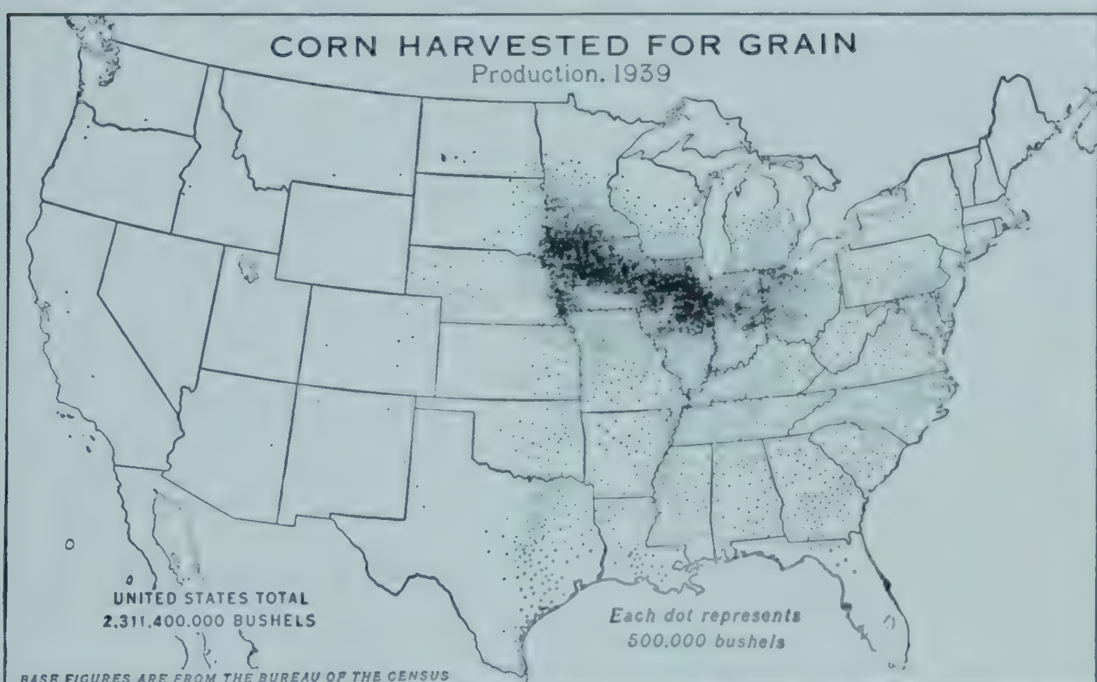


FIG. 10.—Corn production is concentrated in the corn belt and coincides rather closely with the region where most of the country's hogs are fattened. (*Courtesy of the U.S. Department of Agriculture.*)

Grain Sorghums.—The grain sorghums are very important crops in those states where corn is hazardous primarily because of soil moisture deficiencies. They offer much the same type of feed as corn and are used in the feeding program in the areas where grown. The grain sorghums do not enter into world trade to any extent and for the most part are utilized in the sections where they are produced.

TABLE 16.—PRINCIPAL GRAIN SORGHUM STATES, PRODUCTION IN BUSHELS

State	1933–1942	1944
Texas	33,790,000	96,724,000
Kansas	11,189,000	49,468,000
Oklahoma	7,784,000	12,915,000
California	4,504,000	3,920,000
New Mexico	2,218,000	5,560,000
Nebraska	1,691,000	2,244,000
United States total	65,362,000	181,756,000

All types and varieties of grain sorghums are grouped together in Table 16. Production was increased owing to the demands of war, and in 1944 the total United States production was nearly three times that of the 10-year period 1933–1942.

Review Questions

1. What factors are responsible for the distribution of crops?
2. Why should the farmer be interested in world-production figures?
3. What are the relationships between important crop-producing areas and strong nations?
4. Which crop probably leads all others in determining the value of all grain crops? Explain.
5. Explain why Argentina and the United States are competitors in the world markets.
6. Why has China not been an important exporting country?
7. What are the relationships between the uses of a given crop and its market value?
8. Oats are not considered a valuable cash crop, yet many farmers grow them. Why?
9. What are the relationships between standards of living and the use of an animal or vegetable diet?
10. Which type of diet will support the greatest population?
11. Why is it possible for Argentina to compete with Middle Western flax producers in spite of a high tariff?
12. Outline the reasons why the United States is such a great corn country.
13. How is corn production related to hog production?

14. When would you grow grain sorghums in preference to corn?

15. Why is Kansas the leading wheat-producing state?

16. Learn the important states in each of the principal wheat belts of the United States.

17. How does hard red winter wheat differ in grain characteristics from soft red winter wheat?

18. Why is most of the rye grown on light soils?

19. Explain the high rank of Iowa in oat production.

20. Where is barley grown as a substitute for corn?

21. Why do so few states raise flax?

22. Where is most of America's rice produced?

23. Why is buckwheat not grown more extensively?

24. How has hybrid corn affected production?

25. What is the general level of rainfall in the principal grain sorghum producing states?

References

United States Department of Agriculture, *Agricultural Statistics*, current issue.

United States Department of Agriculture, *Crops and Markets*, current issue.

CHAPTER IV

CROP ROTATION

In the early days of agriculture it was not uncommon for farmers to grow the same crop more or less continuously on the same land. Not much thought was given to the problems of soil conservation since there was new land to be had if the farm was worn out. In fact, it was the custom of many of the early farmers to farm an area as long as the yields were profitable and then to move westward to new land of virgin fertility. Now that there are no new lands to exploit, farmers have been forced to give more and more consideration to so operating the farm that it may be maintained in a high state of productivity. One of the methods of maintaining fertility is to follow a definite cropping program. A crop rotation may be defined as a planned sequence of crops grown in recurring succession on the same area of land. In short, provision is made for the growing of different crops rather than the continuous culture of one crop, a scheme that is limited to relatively few crops.

THE ADVANTAGES OF CROP ROTATION

Many advantages may be given for the use of a properly planned crop-rotation scheme. Among these are the following:

1. The diversification of labor so as to provide for better distribution throughout the year. It is much easier to utilize labor that is employed on a yearly basis than to be forced to depend upon seasonal labor. Many grain growers have suffered losses because temporary labor was not available at harvest time.

2. Different crops require different amounts of plant nutrients. A variety of crops aids in the maintenance of fertility since the drain is not so great on any one nutrient.

3. The use of a cultivated crop in the rotation aids in weed, insect, and disease control. Without a rotation weedy plants, insects, and diseases tend to become more numerous, since there is less check to their continued increase in population.

4. The growing of legumes in the rotation aids in increasing the nitrogen content of the soil, as properly inoculated legumes take nitrogen from the air.

5. The risks of financial loss from unfavorable weather, weed competition, and insect and disease damage are reduced by diversification. For example, hot weather at the time of flowering may prove detrimental to corn.

6. Rotations that include sod crops aid in the control of erosion. The sod greatly slows the movement of water and may be interspersed with cultivated areas to prevent erosion.

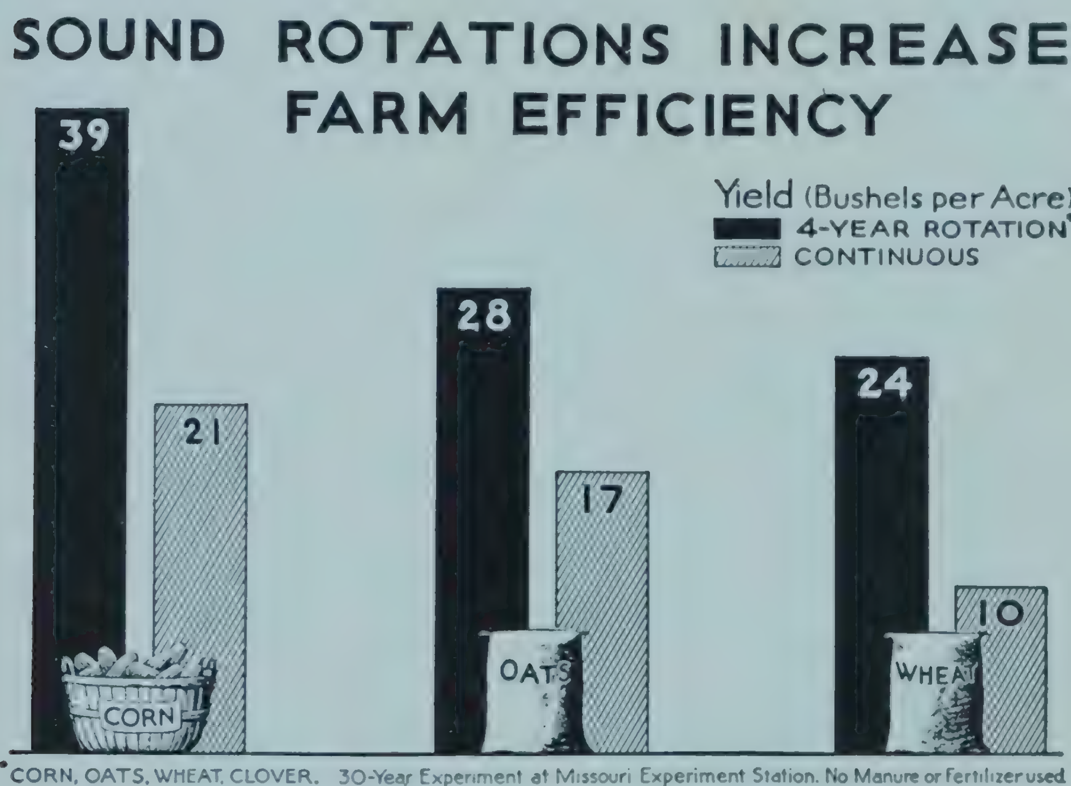


FIG. 11.—Average yields of corn, oats, and wheat in a 4-year rotation and continuously cropped at the Missouri Agricultural Experiment Station. (*Courtesy of the U.S. Department of Agriculture.*)

7. Well-planned rotations make it possible to add farm and commercial fertilizers to the crop that is most likely to bring the greatest financial returns.

8. Crop residues may be returned to the soil and thus aid in the maintenance of organic matter. It is desirable that straw produced on the farm be returned in the manures. Stubble and other crop residue may be plowed under to advantage under most farm conditions.

9. A diversification of crops through crop rotation entails less risk from unfavorable prices on the market. In some years, certain grains command more favorable prices than others according to the market demands.

10. Crop rotations are profitable. In the final analysis the farmer who practices crop rotation usually is the one who has the most profitable enterprise.

Labor Distribution.—The availability of farm labor has been a serious problem during recent years. Most farmers realize that transient labor is less desirable than home labor. In general, the transient laborer demands more pay and is less interested in his job than a local worker. The farmer who is able to arrange his farm enterprises to use a local man is likely to be much more certain of his help when needed. As a rule, a laborer who is assured of work throughout the year is willing to work at a lower rate. This means that if the man can be kept busy in all seasons, the net cost per unit of labor is reduced. It is recognized that many farms do not lend themselves to this arrangement. Such a plan works out best on the livestock farm. The large grain farmer of the Dakotas or Kansas must depend upon seasonal labor. The greater use of power machinery has simplified his problems somewhat, as one man now takes the place of several workers in the days of the steam thresher.

Crop Requirements.—The grain crops in general are rather heavy users of the mineral elements. Unlike the legumes they cannot fix nitrogen and for their best development use large quantities of nutrients. The elements most extensively used in the production of the grains are nitrogen, phosphorus, calcium, and potassium. Magnesium is of considerable importance, but relatively small amounts are required. The grain crops as a whole are not high in their content of nitrogen, yet when considered on an acre basis the requirements are great. The seed is very rich in phosphorus, therefore we might expect grain crops to respond to phosphorus-bearing fertilizers. Considerable calcium is found in the leaves of the grain plant and it is believed to be essential to root development. Potassium is known to be very necessary to the metabolism of crops. The grain crops on the whole remove large quantities of plant nutrients from the soil.

From the data in Table 17 it is evident that the grain crops take large quantities of nitrogen, phosphorus, and potassium from the soil. Lesser amounts of calcium and magnesium are required. It is interesting to note that buckwheat requires a great deal of calcium for its straw. On the whole, corn removes relatively more from the soil than the other grain crops. With many hybrid varieties yielding much more than the 50 bu. given in the table, it is evident that corn requires a soil of high fertility. As a rule, corn is given the choice place in the rotation so as to provide it with the best possible opportunity to pro-

duce well. Flax, wheat, and barley are generally given more favorable places in the rotation than rye, oats, or buckwheat. Of the latter three

TABLE 17.—AMOUNTS OF PLANT NUTRIENTS IN GRAIN CROPS*

Crop	Yield	Nitrogen (N)	Phosphorus (P_2O_5)	Potash (K_2O)	Calcium (CaO)	Magnesium (MgO)
Barley, grain	35 bu.	29.4	12.6	8.4	0.7	2.0
Straw	1,600 lb.	13.4	4.5	24.6	3.7	1.1
Total		42.8	17.1	33.0	4.4	3.1
Buckwheat,						
Grain	20 bu.	15.0	6.0	3.0		
Straw	5,000 lb.	62.5	7.5	57.5	34.5	6.0
Total		77.5	13.5	60.5		
Corn, grain	50 bu.	46.4	18.2	11.0	0.4	3.0
Stover	3,000 lb.	30.0	9.0	42.0	14.2	2.5
Cobs	500 lb.	2.0	0.4	2.2	0.1	0.1
Total		78.4	27.6	55.2	14.7	5.6
Flax, grain	15 bu.	30.5	12.5	8.2	2.8	
Straw	1,800 lb.	20.5	3.4	18.8	13.2	
Total		51.0	15.9	27.0	16.0	
Oats, grain	50 bu.	32.0	13.0	9.6	1.6	1.9
Straw	2,500 lb.	16.0	5.0	31.2	7.5	3.5
Total		48.0	18.0	40.8	9.1	5.4
Rye, grain	20 bu.	19.1	9.8	6.7	0.5	1.3
Straw	2,000 lb.	10.0	6.0	17.0	4.4	1.4
Total		29.1	15.8	23.7	4.9	2.7
Wheat, grain	25 bu.	30.0	12.8	6.0	0.6	2.0
Straw	2,500 lb.	12.5	3.8	15.0	5.2	1.5
Total		42.5	16.6	21.0	5.8	3.5

* Adapted from C. E. Millar and L. M. Turk, "Fundamentals of Soil Science," John Wiley & Sons, Inc., New York, 1943.

crops, probably rye is often grown on the poorer soils because of its ability to yield well under rather adverse conditions. Buckwheat is a more specialized crop and usually is given a better spot than rye or oats.

As indicated earlier, the oat crop is frequently grown primarily because it fits into many types of rotations and serves well as a companion crop for small seeded legumes and grasses. The ability of the oat to produce well in comparison with other crops is well illustrated in a study made by Hayes at the Minnesota Agricultural Experiment Station in which the different grain crops were compared on similar soils and under like conditions.

The data in Table 18 show that at Waseca, Minn., where all crops were grown under comparable conditions, corn yielded the greatest quantity of total digestible nutrients. It is interesting to note that both

TABLE 18.—AVERAGES FOR YIELD AT THE WASECA, MINN., EXPERIMENT STATION, 1921–1942*

Crops	Bushels per acre	Price per bushel	Value per acre	Pounds per acre	Digestible protein, lb.	Total digestible nutrients, lb.
Barley	50.9	$0.48	$24.43	2,443	227	1,923
Corn	64.7	0.53	34.29	3,623	264	2,989
Durum wheat	27.8	0.89	24.74	1,668	193	1,401
Flax	18.2	1.79	32.58	1,019	218	1,108
Hard red spring wheat	24.3	0.92	22.36	1,458	169	1,225
Oats	71.1	0.30	21.33	2,275	214	1,627
Rye	36.7	0.58	21.29	2,055	212	1,646
Winter wheat	29.2	0.91	26.57	1,752	203	1,472

* Adapted from H. K. Hayes, Comparative Values of Crops for Different Sections of Minnesota, *Minn. Agr. Expt. Sta. Bull.* 365, 1943.

oats and rye, the so-called poor-soil crops, yielded a greater quantity of total digestible nutrients than spring, durum, or winter wheat. On a value-per-acre basis both rye and oats were low, largely because of the low bushel price of each. Minnesota farm prices for the years grown were used in the computation of crop values. At the Crookston, Minnesota, Station, for the same 10-year period, barley excelled oats in the production of total digestible nutrients by only 3 lb. The Waseca Station is located in south central Minnesota, in the corn belt, while Crookston is in the black soil region of the Red River Valley.

The Cultivated Crops in the Rotation.—Many areas of the United States are badly infested with weeds; largely because in their early agricultural history one-crop farming was the rule. Probably no other section illustrates this better than parts of Minnesota and the Dakotas,

where wheat was grown almost continuously for many years. The result of this plan has been that many farms are badly infested with the mustards, foxtails, wild oats, wild buckwheat, and many other weeds favored by the one-crop system. The use of cultivated crops has followed the introduction of rotation systems so that today many of these farms are being cleaned of their heavy weed population. Many of the worst

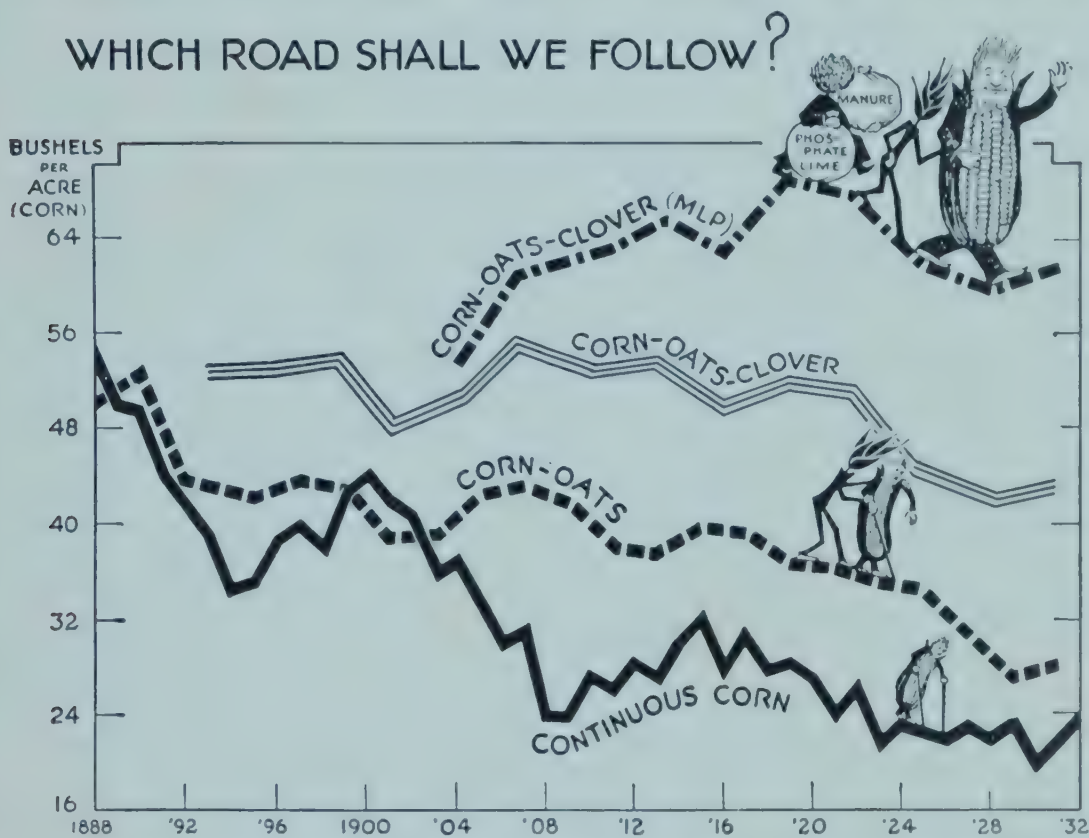


FIG. 12.—Yields of corn grown continuously; corn grown in a 2-year rotation of corn and oats; and corn grown in a 3-year rotation of corn, oats, and clover, with and without fertilizer, on the Morrow field plots of the University of Illinois. (*Courtesy of the U.S. Department of Agriculture.*)

infestations will require years of proper management to eliminate the damage done, as numerous weed seeds are capable of remaining viable in the soil for years.

The value of alternating a crop like corn with oats is illustrated in the long-time Illinois rotation trials.

The 1888–1903 period covers 16 crop seasons, and 1904–1926 includes 23 crop seasons. The yield of corn for the long period was a little more than 10 bu. per acre higher on the plots that had a 2-year rotation of oats and corn than the plots which grew corn continuously. In neither case was any fertility added. The differences are due entirely to the rotation followed.

A study reported by Chen and Arny[1] shows an advantage of rotation even when manure was added to the soil. The plots located at Uni-

TABLE 19.—SUMMARY OF YIELDS FROM MORROW PLOTS, URBANA, ILL., 1888–1926*

Years	Yield, bu. per acre		
	Corn every year	Two-year rotation	
		Corn	Oats
1888–1903	39.7	41.0	44.0
1904–1926	25.1	35.6	34.0

* Adapted from E. E. DeTurk, F. C. Bauer, and L. H. Smith, Lessons from the Morrow Plots, *Ill. Agr. Expt. Sta. Bull.* 300, 1927.

versity Farm, St. Paul, Minn., were laid out in 1909. Previous to that date all plots had received four applications of manure at the rate of 10 tons per acre. After 1909, all plots were manured at the rate of 2 tons per acre each year.

TABLE 20.—CORN AND OAT YIELDS FROM DIFFERENT CROPPING SYSTEMS IN 5-YEAR PERIODS FOR 30 YEARS, 1910–1939, UNIVERSITY FARM, ST. PAUL, MINN.

Period	Corn		Oats	
	Corn every year	Corn and oats in rotation	Oats every year	Oats and corn in rotation
1910–1914	43.2	45.6	46.6	54.9
1915–1919	37.6	37.0	57.9	80.5
1920–1924	39.9	38.0	43.2	60.0
1925–1929	32.6	37.2	50.7	67.6
1930–1934	21.4	30.7	41.8	53.7
1935–1939	45.2	52.8	50.4	60.3
Average 1910–1939	36.7	40.2	48.4	62.8

Although fertility was added, yields were increased by rotation. Considering the long-time average, there was an advantage of 3.5 bu. of corn and 14.4 bu. of oats. The difference in the case of corn approached significance when analyzed statistically, while the yield differences of the oats were highly significant.

[1] CHEN, H. Y., and A. C. ARNY, Crop Rotation Studies, *Minn. Agr. Expt. Sta. Tech. Bull.* 149, 1941.

Insect pests tend to become more troublesome if the same crop is grown year after year, as there is a tendency for the population to increase at a more rapid rate. For example, if corn is grown in successive years, the corn borer finds a more favorable environment and is more of a problem than would be the case if a rotation were followed Another good example is the chinch bug. This insect is especially destructive to corn and wheat. If the infested field can be planted to a clover or alfalfa crop, the insect will not find so favorable an environment and will be greatly checked.

Certain plant diseases tend to become more serious if the same crop is grown in succession. Once a soil becomes infested with disease organisms, a planned rotation will often do much to reduce recurring injury. Under certain conditions, soils become infested with the scab organism (*Gibberella saubinetii*). As it attacks both corn and barley, it may become so prevalent in corn stubble as to occasion serious losses to the barley crop that follows. In the Pacific Northwest the bunt or stinking smut spores live over in the soil, and when wheat follows wheat there is a tendency for the disease to increase in prevalence. Many other examples might be given to illustrate similar advantages of rotation in disease control.

Legumes in the Rotation.—Most good farmers plan to incorporate a legume in the rotation. Not all legumes are of equal value as soil builders since some of the large seeded types, such as the soybean, grown for seed, are actually soil-depleting, much the same as a cereal grain crop. Alfalfa, the clovers, lespedeza, and similar crops aid materially in maintaining fertility if properly utilized. On many farms there is a tendency to remove all the hay each year with no return. Under these conditions the legume is of little or no value in soil improvement. Many years ago, Hopkins[1] stated that

> . . . on normally productive soils at least one-third of the nitrogen contained in legume plants is taken from the soil, not more than two-thirds being secured from the air. This proportion would apply to the nitrogen content of the roots as well as to the tops, so that, if one-third of the nitrogen of the entire plant is in the roots and stubble, and two-thirds in the crop harvested, the soil would neither gain nor lose in nitrogen because of the legume crop having been grown, the soil having furnished as much nitrogen to the plant as remains in the roots and stubble.

When the legume is pastured, considerable benefit is gained from the

[1] Hopkins, C. G., "Soil Fertility and Permanent Agriculture," Ginn and Company, Boston, 1910.

animal droppings. Also, under average conditions, leaves and stems are left on the soil and add to the fertility to some extent. It is advisable, however, where the hay is harvested, that barnyard manures be applied insofar as possible to maintain fertility. The incorporation of a legume in the rotation does exert a marked effect on the productivity of most soils. The less fertile the soil, the greater is the effect if normal growth is obtained.

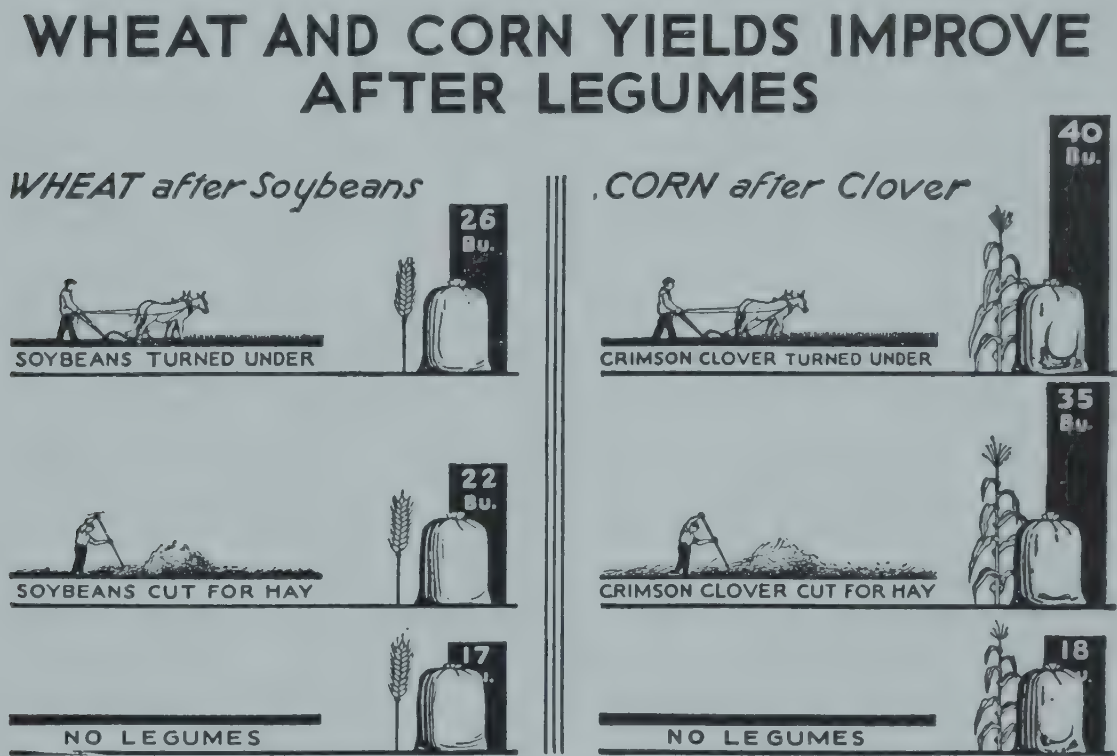


FIG. 13.—The 7-year average yields of wheat and corn following legumes turned under, legumes harvested for hay, and nonleguminous crops at the Virginia Agricultural Experiment Station. (*Courtesy of the U.S. Department of Agriculture.*)

DeTurk *et al.* have shown the effect of including a legume in the rotation. As shown in Table 21 in the 3-year rotation, the average corn yield in the period 1888–1903 was 48.0 bu. and had increased 18.6 bu. in the second period, 1904–1926, while in the continuous corn plot the average yield had decreased 16.6 bu. per acre.

Similar results have been reported by Wiggans[1] in New York trials. He showed a great advantage in yield from the inclusion of a legume in the rotation and also demonstrated the benefits of the use of commercial fertilizers and manure. Good rotations without manure were nearly as effective in producing oats and wheat as heavy applications of complete fertilizer on crops grown in continuous culture.

It should be remembered that the better the growth of the legume, in general, the better will be the effect on soil fertility. A poor stand,

poor inoculation, or a run-down weedy field cannot be expected to give the benefits of a productive field. In many instances it will pay to fertilize the legume crop to promote better and more productive growth.

Rotations Spread the Risks.—At its best, farming is a gamble since the farmer is at the mercy of many factors of the environment. It is true that he can purchase hail insurance, but he cannot guard against drought, storms, and in some instances insect or disease damage. The use of improved varieties of farm crops has done much to stabilize production and to guard against the serious problems of surpluses. In the

TABLE 21.—SUMMARY OF YIELDS FROM MORROW PLOTS, URBANA, ILL., 1888–1926*

Years	Corn every year, bu.	Three-year rotation		
		Corn, bu.	Oats, bu.	Clover, tons
1888–1903	39.7	48.0	47.6	2.03
1904–1926	25.1	66.6	62.7	2.40

* Adapted from E. E. DeTurk, F. C. Bauer, and L. H. Smith, Lessons from the Morrow Plots, *Ill. Agr. Expt. Sta. Bull.* 300, 1927.

years of shortage, farmers may be influenced into greatly increasing their production of a particular crop. Frequently this results in disaster as many others may follow the scheme and an overproduction results in prices that mean little or no profit. The farmer who follows a planned program with a diversification of crops known to be adapted to his region is likely to be better off than the farmer who continually attempts to guess as to the probable demands for a given crop.

As indicated earlier, in the discussion of crop adaptation, each particular to crop has its own requirements. The bad weather for one crop may be beneficial to another. In certain years barley fails to produce a good crop, and many farmers vow never to grow barley again. A favorable year follows sooner or later; the barley production is so low that the demand exceeds the supply; prices skyrocket, and the average farmer wishes he had some barley to sell. This happens so frequently that it is a serious economic problem.

In 1943, much of the Middle West was subjected to heavy rains, making it impossible to plant spring crops at the usual time. In some cases, farmers were unable to seed their small grains at the proper time.

[1] WIGGANS, R. G., Experiments in Crop Rotation and Fertilization, *Cornell Univ. Agr. Ext. Bull.* 434, 1924.

However, the fall frosts did not come early, and the region experienced one of its most productive crop years.

The farmer who grows only one crop, such as potatoes, may lose everything, as it is not uncommon for a disease such as blight to strike and virtually destroy the crop. The winter wheat may be severely injured, but on the diversified farm there is the rye or the spring wheat, oats, or barley to fall back upon. The farmer of the Northern states may lose his corn crop by early frost, but he will still have valuable hog feed if he has a bin filled with barley.

Rotation and Soil Erosion.—The loss of our fertile top soils is greatest on those farms where the operator insists on the continuous use of cultivated crops. Whether for corn or cotton, the net effect of continuous cultivation is the rapid depletion of organic matter and subsequent erosion. The use of adapted grasses and legumes adds organic matter to the soil and thus binds it together so that it is less subject to damage from water runoff. The very nature of tillage breaks down organic matter that must be returned to avoid serious soil losses. The remedy does not lie in the discontinuance of tillage but rather in supplementing tillage with a sane program of replenishment.

Many farms have fields that are too steep to warrant the growing of tilled crops, and such areas should be maintained in grass crops. In some cases contour farming or strip cropping may be successful. If either is used, the sod crop is of great importance as it is used to check the rapid movement of water. On a slope the water tends to cut a ditch or gully in cultivated soil, whereas on a grass area it tends to slow up and spread out into a wide movement which does little or no damage. The good farmer leaves grass or sod strips in the natural drainage-ways of the fields, by lifting the plow at the time of crossing the field depressions. Many of the gullies of our fields could have been prevented through the use of a little care in leaving sod strips.

Fertilizers in the Rotation.—On livestock farms it should be a cardinal rule that all manures be returned to the soil. This should include all fields and not just the fields near the farm buildings. Many farmers would never think of applying manure to their pastures or meadows, yet these may be their most profitable fields.

The quality of manure varies widely; the class of animal, its age, and the type of feed all affect the manure produced. It is not uncommon for the manure to be piled up at the rear of the barn to be subjected to leaching and other losses that may destroy a large percentage of its value. Since about one-half of the value of manure is in the urine, it is clear that improper storage results in great losses.

It is common to apply manure just before the principal cash crop. In the grains this often would be before corn, grain sorghums, or flax. On most soils the application of manures just before the other grain crops is likely to result in considerable lodging of the plants because of the excess nitrogen released from the manure. If a rotation of corn, oats, and clover is grown, the manure may be applied on the clover stubble just before it is plowed under.

Farmers can learn about the probable needs of their soils by consulting their county extension workers or by writing to their state agricultural experiment station. If commercial fertilizers have never been used, it is well to try them on a limited scale to observe whether they benefit or not.

Crop Residues.—Some farmers insist on burning their cornstalks and straw piles. If the stalks are infested with corn borers or the straw stack is filled with the seeds of noxious weeds, then the practice may be a good one. Virgin soils are usually well supplied with organic matter, but the continuous removal of all crop materials with no return can result in just one thing—depletion with subsequent deleterious effects. Earlier in this chapter, figures were given on the amounts of fertilizing elements in the different grain crops. It is only logical that, if a portion of these crops is returned to the soil, the soil is replenished to that extent.

The supply of nutrients and organic matter in the soil is like a bank account. The less there is withdrawn at any one time and the fewer the withdrawals made, the longer the time will be before there is an overdraft. Fortunately, Nature does not permit an overdraft. Long before the last bit of fertility is exhausted, the farm will be abandoned as has been done too often in the past. The more of the residues preserved and returned to the soil, the longer will be the period when adequate returns may be obtained from the soil.

In areas where rainfall is quite low and it is necessary to practice summer fallow, the plowing under of crop residues may result in tying up the water supplies with subsequent crop failure. However, in the more humid areas this is not likely to occur. For some time after a heavy crop of straw has been plowed under there may be a temporary reduction in productivity because the bacteria living on the cellulose of the straw tend to tie up the available nitrates. This effect is only transitory, and soon the fertility will be released with the decomposition of the residues.

Markets and Rotations.—This is somewhat different from the risk of a total crop failure as a result of a one-crop plan, but it is a definite problem for the farmer. Occasionally there is such a shortage of a

desirable grain that prices are exceedingly high and there is great danger that this may bring about overproduction the next year. For many years durum wheat was not a profitable crop compared with bread wheat, largely because more durum wheat was produced than was needed for making macaroni. In recent years, the producer of high-quality durum wheat has been able to command a premium on the market. The student of economics knows of the programs instituted by the government to bolster farm prices during the years of great surpluses to meet this national problem that affected all growers of the surplus crops. The farmer who does not diversify runs the risk of ruinous prices because of an oversupply of a given crop. Malting barley, for example, brings a premium over feed barley in many years. Yet it would not seem wise for a farmer to plan to produce only malting barley. The desirable practice is to grow a high-yielding variety that may be used for feed or sale or both, depending upon the economic conditions that exist. This gives the grower an added insurance and should make barley production more profitable. It may develop in a given year that it is better to feed livestock than to sell cash grain, even though prices for cash grain were very favorable the preceding year.

Rotations and Profit.—The last topic is in reality a summation of the others. The practices which better the farmer's situation should all lead to more profitable enterprises. They should likewise result in a better farm as the years pass. The farm is the farmer's estate, and as such his practices should be designed to lead to its improvement and thus safeguard it as a permanent income-producing investment.

PLANNING A ROTATION

It must be remembered that a rotation is based upon certain principles that are related to the specific area involved. It is impossible to plan proposed rotations for all areas. Instead, a few type rotations will serve to illustrate the general plan that may be followed for all sections.

One of the simplest and most commonly used rotations in much of the corn belt is the following 3-year plan:

Cultivated crop, as corn or sorghum
Small grain crop, as oats, wheat, or barley
Grass or legume crop, as clover

This is a short-time rotation that provides a fair balance between crops. The small-grain part of the rotation may include two or more small grains. The grass or legume crops may be all hay or part hay and part temporary pasture. The final arrangement will depend upon the

system of farming followed, the number and class of livestock, the market situations, the soil, and other environmental factors.

In sections where alfalfa may be grown, the rotation may be lengthened so as to leave the fields in alfalfa for two or more years. Such a rotation is as follows:

Cultivated crop
Small-grain crop
Alfalfa for 2 or 3 years

Note that the cultivated crop always follows the grass or legume crop, as this offers the best opportunity to take advantage of the greater fertility available at this time. In the above rotations, it is assumed that the legume or grass crop is seeded as a companion crop with the grains.

In some sections use has been made of what is actually a 2-year rotation:

Cultivated crop
Grain crop (with legume seeded in)

The legume crop, usually clover, is permitted to grow until late fall or spring when it is plowed under and the land again planted to corn. When biennial sweet clover is used in this rotation, it is advisable to plow in the spring, or the clover may prove to be a troublesome weed in the corn field.

The Missouri Agricultural Experiment Station has developed a lespedeza small-grain annual rotation that has proved successful in that state.[1] Under this plan the rotation is as follows:

Small grain (with lespedeza)

The rotation is put into operation by seeding the lespedeza on a crop such as wheat in winter or early spring. Soon after the wheat is harvested in June, the lespedeza is pastured, cut for hay or seed or used for both. In the fall when the lespedeza seed approaches maturity, the land is disked and again sown to wheat. This scheme greatly reduces the labor required as it is not necessary to use the plow. Also such a plan aids greatly in checking erosion from heavy rainfall since the soil is held by the lespedeza during most of the year. It is evident that it is necessary to use fertilizer even with this plan because the mineral elements, in particular, are continuously removed from the soil.

[1] ETHERIDGE, W. C., Efficiencies of the Lespedeza–Small Grain Annual Rotation in Missouri, *J. Am. Soc. Agron.*, Vol. 35, No. 3, 1943.

On fertile soils many farmers grow corn 2 years in succession, using a rotation such as the following:

Corn
Corn
Small grain
Legume or grass crop

If this plan is followed, it is desirable to use considerable manure and to apply commercial fertilizers as needed.

The advent of the soybean in much of the crop-producing area has led to new types of rotations. The soybean grown for seed should not be considered a soil-building crop but rather on the same basis as a small grain. A rotation of this type would be as follows:

Corn
Soybeans
Small grains
Legume or grass

This is a rather heavy feeding rotation, since 3 years of soil-depleting crops are used. It is successful, however, if use is made of manures and commercial fertilizers are added as needed.

In the East, a plan often referred to as the *Pennsylvania rotation*[1] is the following:

Corn
Oats
Wheat
Hay

There are many other schemes of cropping, usually based upon a planned sequence to give the greatest returns in keeping with the maintenance of soil fertility. The incorporation of specialized crops such as tobacco or canning crops requires modification, but the general pattern is very much the same. If the student is familiar with the principles underlying a good crop rotation, he can easily plan a sequence that is suited to any section or any group of crop plants.

It is one thing to plan a rotation on paper and another to carry it through to completion. It is unusual for a farmer to be able to carry out his rotations for long without interruption. A severe winter freeze

[1] WRIGLEY, P. I., Types of Farming in Pennsylvania Vary with Climate, Soil, and Market Demands, *Penna. Agr. Expt. Sta., 57th Ann. Rept., Supplement* 1, *Bull.* 464, December, 1944.

may destroy the legume crop and upset the rotation. Under these conditions it is necessary to make adjustments, such as the growing of emergency crops. Then the operations are carried out so as to return to the basic plan of the original rotation as soon as practical.

Review Questions

1. What do you understand by the term *crop rotation?*
2. Give the advantages that you may have observed of the effect of crop rotation.
3. Why is diversification of labor important?
4. Is proper crop rotation enough to maintain fertility? Why?
5. How would you utilize crop residues to get their greatest benefit?
6. Why do grain crops tend to respond to applications of phosphate?
7. Why do farmers of the East and South tend to use more commercial fertilizer than the farmers in the Middle West?
8. What changes are occurring in the attitudes of the Middle Western farmer?
9. What proof can you offer that it is best not to burn straw?
10. What crop usually is given the choicest place in the rotation?
11. Study the figures in Table 17 and explain their meaning.
12. Why should a farmer be concerned with the total digestible nutrients produced by a crop?
13. What important facts are illustrated by the yields from the Morrow plots?
14. Why do insect pests and diseases tend to become worse where no rotation is followed?
15. Does the growing of a legume that is harvested for hay with no manure returned improve fertility? Explain.
16. How does crop rotation aid in erosion control?
17. In what way does a proper rotation aid in erosion control?
18. Where in the rotation should manure be applied?
19. Why does manure tend to produce lodging in small grains?
20. How are commercial fertilizers applied to grains?
21. Why should a farmer observe market demands in planning his rotation?
22. Work out two or three rotations for your home farm.
23. What is meant by a rotation within a rotation?
24. What must one do in case of winter killing and an upsetting of the planned rotation?

References

Baker, G. O., and K. H. W. Klages: Crop Rotation Studies, *Idaho Expt. Sta. Bull.* 227, 1938.

Engene, S. A., and G. A. Pond: Agricultural Production and Types of Farming in Minnesota, *Minn. Agr. Expt. Sta. Bull.* 347, 1940.

Gustafson, A. F.: "Soils and Soil Management," McGraw-Hill Book Company, Inc., New York, 1941.

McIlvaine, T. C., and G. G. Pohlman: Crop Rotation Experiments in the Ohio Valley (1925–1936), *W. Va. Agr. Expt. Sta. Bull.* 306, 1943.

Meyer, B. S., and D. B. Anderson: "Plant Physiology," D. Van Nostrand Company, Inc., New York, 1939.

Miller, E. C.: "Plant Physiology," 2d ed., McGraw-Hill Book Company, Inc., New York, 1938.

SALTER, R. M., and J. O. LILL: Crop Sequence Studies in Northwestern Ohio, *J. Am. Soc. Agron.*, **32**: 627–630, 1940.

SARVIS, J. T., and J. C. THYSELL: Crop Rotation and Tillage Experiments at the Northern Great Plains Field Station, Mandan, N. Dak., *U.S. Dept. Agr. Tech. Bull.* 556, 1936.

SCHAFER, E. G., L. C. WHEETING, and S. C. VANDECAVEYE: Crop Rotations, *Wash. Agr. Expt. Sta. Bull.* 344, 1937.

"Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

WHITE, J. W., F. J. HOLBEN, and A. C. RICHER: Maintenance Level of Nitrogen and Organic Matter in Grassland and Cultivated Soils over Periods of 54 and 72 Years, *J. Am. Soc. Agron.*, **37**: 21–31, 1945.

WIGGANS, R. A.: Experiments in Crop Rotation and Fertilization, *Cornell Univ., Agr. Expt. Sta. Bull.* 434, 1924.

CHAPTER V

THE CULTURE OF GRAIN CROPS

In the discussion of crop culture one is not limited to the problems of tillage alone, as properly culture should include all problems relative to the growing of the crop. For this reason culture includes the choice of soils, seed cleaning, seed treatment, seedbed preparation, seeding, cultivation, harvesting, storage, and marketing. Each phase is of significance in grain farming and must be considered if one is to gain a complete picture. Although different crops present special cultural problems, many of the principles are alike, so that unnecessary repetition may be avoided by their consideration as a whole. Where specific deviations from the general principles occur, these will be discussed under the various grain crops.

SOILS FOR GRAIN CROPS

Fundamentally, the United States is endowed with a high percentage of very fertile soils. It is largely for this reason that the nation ranks so high in wealth, since much of our national prosperity revolves around the prosperity of the agricultural group. Geologically, many of our soils are young. The soils of the Eastern sections are old, having been subjected to a long period of erosion and leaching. The soils of the Middle West are young, and here are found some of the world's most fertile soils and a region of great agricultural production. In this section, only in recent years has much use been made of commercial fertilizers. Because of the inherent fertility of the virgin soils, farmers have been able to produce large yields with little or no attention to fertility. This period has passed for the most part, and now the good farmer is following a program that leads to a replacement of fertility elements being removed from the soil.

As a general principle the lighter soils, such as the sands, tend to be low in fertility, whereas the heavier soils, such as the prairie types, tend to be high in fertility. As shown in the map of the soil groups of the United States, the darker colored areas, largely in the Mississippi River Valley, are the most fertile soils and are generally the best suited for the production of the grain crops. The student should note the coincidence of the prairie soils with much of the high-producing area of the corn belt.

Likewise, he should note the great area of chernozem soils and relate them to the production of a large part of the best wheat in America. The word *chernozem* is derived from the Russian and means "black earth." The chernozem soils are found in temperate grassland areas. They have very dark brown to black surface soils with varying types of subsoil

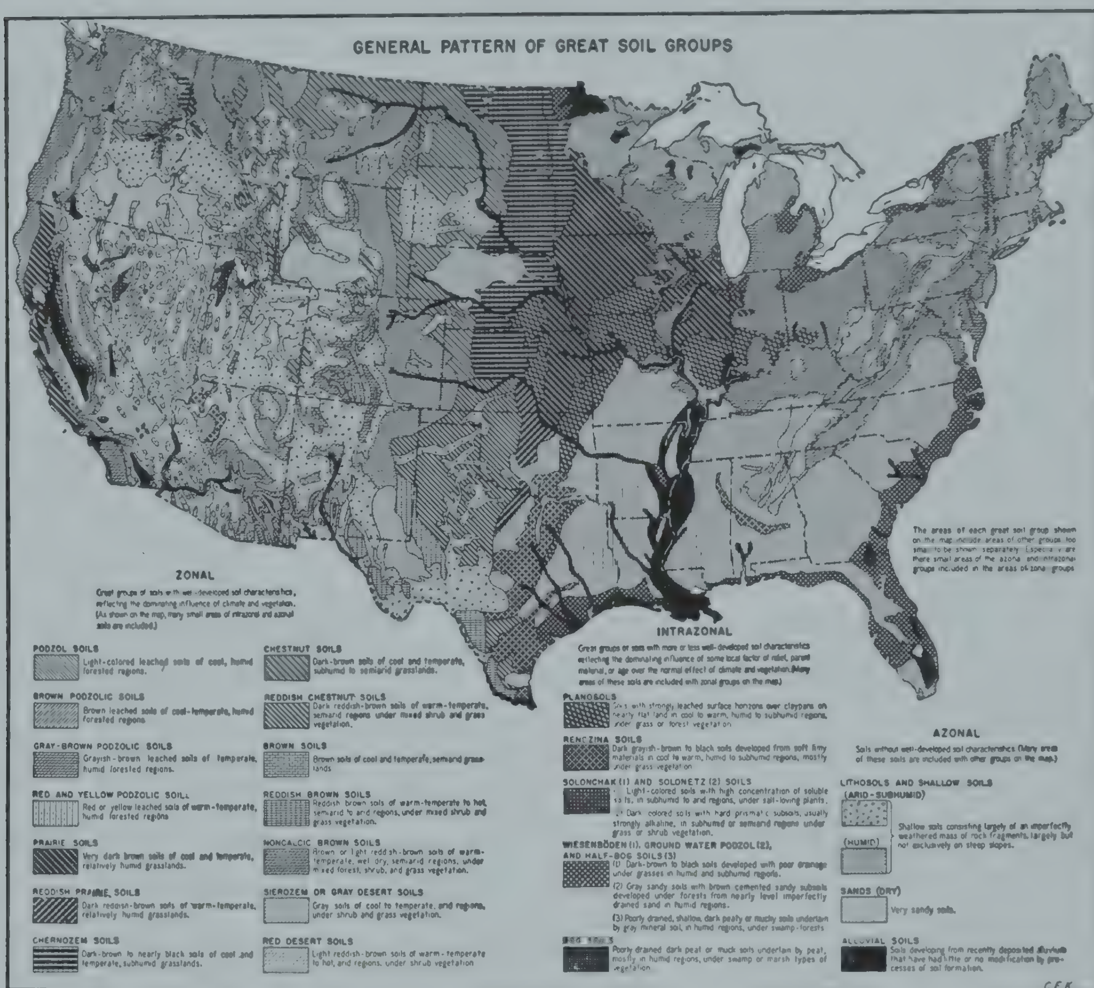


FIG. 14.—General distribution of the great soil groups in the United States. (*Courtesy of the U.S. Department of Agriculture.*)

distinguished by their rather high content of the carbonates, primarily calcium carbonate. They generally are developed where the rainfall varies from 18 to 28 in. annually. These soils are especially suited to the production of the small grains and in the areas of heavier rainfall are important corn sections. The planosols occupy an important place in grain-crop production. Their distinguishing feature is the accumulation of a layer of clay or cemented material at varying depths below the surface. The range of productivity of the planosols is great, varying from very valuable soils to low producing, poorly drained types. Several other soil types are of importance in the grain-producing areas, but

they cannot be discussed in detail here. The student is referred to the excellent discussion of the various soil types in "Soils and Men."[1]

Soils for Corn.—The corn plant is a heavy feeder, requiring large quantities of plant food for its best growth. As indicated in an earlier chapter, a 50 bu. per acre crop of corn removes from the soil 78.4 lb. of nitrogen, 27.6 lb. of phosphorus, 55.2 lb. of potash, 14.7 lb. of calcium, and 5.6 lb. of magnesium. These are generally considered the most essential elements, but to this list must be added several others, each of which is extremely important if insufficient amounts are available for the needs of the corn crop. It is evident that such rapid withdrawal of plant food from the soil will result in depletion unless returns are made, such as green manure, barnyard manure, or commercial fertilizers, or various combinations of these groups.

Corn grows most rapidly during the warmer part of the crop season at a time when nitrification is likely to be most rapid. With plenty of water and available plant food, corn can be grown successfully on a variety of soils, ranging from a fairly coarse sand to the heaviest of clays. In dry years the plant is subject to much damage from drought when grown on light, sandy soils. The moderately heavy clay loam or fine sandy loam is ideally suited to corn production in most areas. The alluvial soils of the river valleys are especially productive and often give very large yields of high-grade corn in average seasons. Farmers who grow corn generally apply manure ahead of the corn, as frequently it is the most important crop of their rotation. No rule can be set, but 8 to 10 tons per acre should be applied at least once in the rotation. The manure is important in that it supplies nitrogen, phosphorus, potash, and organic matter. Under most conditions, much of the fertilizing value of fresh manure never becomes available to the plant as it is lost through improper storage, resulting in loss by decomposition and leaching. This means that even when an abundance of manure is available it becomes necessary, sooner or later, to apply commercial fertilizers. With the proper use of legumes and manures it is usually possible to maintain the supply of nitrogen. Many farmers utilize a phosphorus-bearing fertilizer, applying it either in the hill at the time of planting with a cultivator attachment, as a top dressing, or, according to a more recent method, at the time of plowing the soil. In the latter case the fertilizer is applied in the bottom of the furrow.

Some farmers use a complete fertilizer, *i.e.*, one containing nitrogen, phosphorus, and potash. Probably more soils respond to phosphorus than the other elements. A prime advantage of phosphorus is that, in

[1] "Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

addition to making for a higher yield of better quality corn, it tends to hasten maturity, a factor of great importance in much of the corn belt.

Soils for Sorghum.—The sorghum plant is very similar to corn in its nutritional requirements. It has been stated that sorghum may be grown on a corn soil, and vice versa. It is known, however, that sorghum will produce well on a less fertile soil than corn, but it does respond to high fertility and will succeed with less rainfall and higher summer temperature conditions than will corn. Like corn, the sorghum plant responds to nitrogen and organic-matter applications. The grain types are likely to be benefited by phosphorus treatments on a great many soils in the more humid sections of the sorghum belt.

With plenty of moisture in the soil the sorghum plant often gives way to the corn plant. Its requirements are so nearly the same that the availability of moisture supplies may determine the choice between the two crops.

Soils for Wheat.—As indicated earlier, most of the wheat grown in the United States is produced on fertile soils that formerly were prairies, although much wheat is grown in other sections, particularly in eastern United States. In general, this wheat is produced on soils of lower inherent fertility and the flour tends to be lower in its protein content.

Farmers in the hard red winter and hard red spring wheat areas tend to make wheat their primary cash crop, and under these conditions it is given the best place in the rotation. Few farmers in the hard red winter wheat region follow a rotation. Wheat that is grown in the drier sections is usually preceded by 1 year of fallow so that the moisture of 2 years is made available for the crop. In these sections of limited rainfall it is very difficult to add organic matter to the soil, and as a result some farms have been depleted in organic matter, but this has not been reflected in reduced yields in western Kansas.

To produce wheat of high-protein content it is necessary that the soil be well supplied with nitrogen, and for this reason the prairie soils are well suited to the production of high-quality wheat. These soils were inherently rich in nitrogen as well as the other essential mineral elements. The significance of nitrogen is illustrated by a Minnesota trial in which wheat following sweet clover analyzed 13.57 per cent protein as contrasted with a percentage of 12.36 following a nonlegume.

Many of the wheat soils respond to applications of phosphorus-bearing fertilizers applied as a top dressing or in the row at the time of seeding. The Kansas station reports no response from these treatments. The effect of fertilization is to stimulate the plants to more rapid growth

and thus favor early maturity, a factor of considerable importance in the event of hot weather at the time of flowering.

Soils for Rye.—Rye is peculiar in that although it responds to soil fertilization it has the ability to grow well in soils of limited fertility. Probably more rye is grown on the sandy soils of the country than any other grain crop. If there is sufficient water to make for growth, rye will yield well on soils too sandy to support most other crops. Most farmers do not apply fertilizers to the rye crop, but their use would prove profitable on a great many soils. Applications of both nitrogen and phosphorus are likely to prove beneficial to the rye crop, particularly in the sandy areas.

Soils for Oats.—The oat plant, being best adapted to cool climate, does well on the better soils. It is not well suited to growing on sandy soils unless nitrogen is available. On the light sands it is probable that the plants will be too short for harvesting. Although the oat grows well on soils rich in nitrogen, an excess is likely to result in much lodging of the grain and a poor yield. Most farmers do not use fertilizers on oats, choosing to apply the fertilizer to the cultivated crop, usually corn, that often precedes oats in the rotation. Under average conditions there will be a sufficient residue from the earlier soil treatment to provide benefit to the oat crop that follows.

Soils for Barley.—The barley plant is somewhat like the oat in its soil requirements. It is probable that satisfactory yields of barley cannot be obtained on soils that will produce only a fair crop of oats. The use to be made of the barley should influence the choice of soil and fertilization. When the barley is grown for feed, a soil rich in nitrogen is desirable. On the other hand, if the crop is to be used for malt, some investigators believe that a soil not too well supplied with available nitrogen may, if climatic conditions are proper, produce the desirable starchy type of grain preferred by the maltster. Like oats, barley straw tends to lodge in heavy clay soils. Barley does poorly on sandy soils and yields best on moderately fertile loams. Where it is grown for a cash crop it is given a favored place in the rotation, and it usually does best on good winter wheat soils.

Soils for Flax.—Since flax is grown as a cash crop, it is placed in the most advantageous spot in the rotation. Because of its inability to compete with weeds, it frequently follows a legume or pasture crop. Being a heavy user of nitrogen and phosphorus, flax yields best on fertile loam soils and in some sections responds to liberal applications of fertilizer, especially phosphorus. It does not yield well on light soils under average conditions.

SEED CLEANING

It has been said that the cheapest and most effective weed control lies in the avoidance of infesting the soil with weed seeds through the use of improperly cleaned seed. Far too many farmers make a practice of seeding their grains just as they come from the threshing machine, weed seeds and all. Under these conditions the land is being planted with weed seeds, and in some cases a single year's seeding may give weed problems for many years.

FIG. 15.—A portable seed cleaner and treater in operation on an Indiana farm. (*Courtesy of C. E. Skiver, Indiana Agricultural Experiment Station.*)

The average threshing machine or combine does not do an adequate job of cleaning the seed, and unless supplementary cleaning devices are available there is danger of seeding undesirable weed seeds through the use of such grain. Even when the grain is marketed it will pay to reclean under most conditions, as the cost of transporting the weed seeds and trash to market are assessed against the grain. In addition, many of the weed seeds, such as the foxtails, barnyard grass, and wild buckwheat, are of great value as feed. Properly processed with a hammer mill they may be used to good advantage on nearly every farm.

The farm fanning mill should be an asset, but frequently it is a liability. Many of these mills are improperly operated and fail to do a

good job, and such a mill is worse than no mill. It is probable that most farmers should not expect to operate their own cleaning equipment, since specialized machinery and skills are needed to do the work properly. In nearly every community it is possible to secure the services of the local elevator for seed cleaning. In many districts, transient operators transport cleaning equipment from farm to farm and do custom work. This is a splendid arrangement, and such services should be utilized whenever available.

Some picture of the seriousness of the foulness of crop seeds is illustrated by the dockage in flaxseed. Cox and Brookins[1] found that of 7,413 cars of flaxseed marketed the dockage averaged 11.3 per cent, or the equivalent of about one car of dockage for every 10 cars of clean flax. On this basis, of the 1941 flax crop in Minnesota more than 41,000 tons of dockage was received at the terminal market in one season, requiring the use of the space of 950 cars and costing more than $138,000. The situation as given for flax applies to a certain extent to all the grain crops, although it must be recognized that flax generally carries a higher percentage of weed seeds than other grains since it is an extremely poor competitor.

A primary factor determining the market grades of wheat is the presence of weed seeds. The removal of these weed seeds may raise the market grade to the point where several cents per bushel may be gained. In the hard red spring wheat area, some growers find it advisable to pay the local elevator to clean their grain before it is shipped. This represents a saving in shipping costs, may result in a better price for the grain, and leaves the dockage at home where it may be utilized for feed.

The primary argument for seed cleaning can be made for the seed destined to be planted on the farm. It is impossible to compute the saving in future labor and yield decreases over a period of years when one compares the use of clean seed with that infested with weeds. The planting of grain infested with such noxious weed as field bindweed (*Convolvulus arvensis*) may require years for its elimination from the farm. A little care in cleaning the seed supplies is the best of low-priced insurance against weedy fields.

SEED TREATMENT

The treatment of seed to control diseases is a practical form of insurance for the average farmer. It is the ambition of the plant breeder to

[1] Cox, Rex W., and W. W. Brookins, Dockage in Flaxseed, *Minn. Agr. Expt. Sta. Bull.* 371, 1943.

develop varieties that are resistant to all diseases. In many cases this has not been accomplished, and it still pays to follow definite plans of seed treatment. Some diseases are carried on or in the seed, and these are the ones most easily controlled through the use of chemicals or heat, but such diseases as the rusts cannot be controlled in this manner. These relationships will be treated in detail in the chapter dealing with plant diseases. The various methods of treating seeds for disease control will be discussed in relation to the specific diseases in that chapter.

Value of Seed Treatment.—The proper treatment of the seeds of the grain crops frequently proves beneficial in that many of the common diseases may be partially or completely controlled. The effectiveness of seed treatment must of necessity depend on the variety and crop, the source and condition of the seed, the type of disease organism, the various environmental factors, including the time of planting, and the type of seed treatment used.

Types of Seed Treatment.—In early days the farmer who treated his seed expected to control only the smuts of cereals, and he usually relied upon the old formaldehyde treatment. More recently greater attention has been given to the use of the so-called *mercurial compounds*, many of which have proved of great value in human medicine. The two general groupings of seed treatment are chemicals and heat, the former being used to destroy organisms carried on the surface of the seed whereas heat treatment is employed to destroy the organism that is carried within the seed and thus not subject to external applications of chemicals.

Chemical treatments are of two general types: the dry dust and the wet spray. The latter method has been replaced to a large extent by the dusts, not only because of their greater convenience but also because of their effectiveness in securing disease control. The use of the various treatments in relation to the various crops is discussed in Chap. VII.

SEEDBED PREPARATION

From the earliest times when man used a crooked stick for a plow until the present day, there has been considerable controversy regarding the methods of seedbed preparation. There have been advocates of deep tillage and others who favored very shallow cultivation. The interest in the subject is illustrated by the fact that a recent book in which the author advocated the elimination of the plow has been widely read and has stimulated considerable discussion.

Few theories or statements of opinion on tillage have resulted in

more controversy than the book by Edward H. Faulkner.[1] The essence of Faulkner's thesis is that the moldboard plow is of no value and that its use is resulting in the rapid destruction of soil resources. Several scientists have taken exception to the viewpoint of Faulkner and have shown the fundamental reasons for plowing as a means of seedbed preparation. Typical of the evidence in favor of the plow are two articles by Dr. W. A. Albrecht, head of the department of soils, University of Missouri. In the articles[2] Dr. Albrecht presents scientific evidence to support his viewpoint that the plow is a useful implement and should be used by many farmers.

Fig. 16.—The one-way plow followed by a packer on a Kansas farm. This is an excellent way to prepare a seed bed for winter wheat or barley. (*Courtesy of A. F. Swanson, Kansas Agricultural Experiment Station.*)

It is recognized by most scientists that much harm has resulted from the careless use of the plow. The value of the mulch as advocated by Faulkner is generally appreciated, but there are wide differences of opinion as to the proper limits of its use.

Browning and Norton[3] report that the greatest advantages of the plow are on poorly drained, poorly managed, or heavily farmed lands.

[1] Faulkner, E. H., "Plowman's Folly," University of Oklahoma Press, Norman, 1943.

[2] Albrecht, W. A., Why Do Farmers Plow, *Better Crops with Plant Food Magazine*, reprinted and distributed by the American Potash Institute, Inc., Washington, D. C., 1943.

[3] Browning, G. M., and R. A. Norton, More Seedbed Studies, *Iowa Farm Science Reporter*, **7**: 10–13, 1946.

On eastern Iowa soils where tillage trials were made, plowing usually gave the highest yields of corn except on Tama silt loam. In certain areas where erosion was a problem, soil losses were greatest with the plow.

Many experiments have been conducted by the various agricultural experiment stations on time of plowing and depth of plowing, and similar studies seeking to learn the practices most conducive to efficient

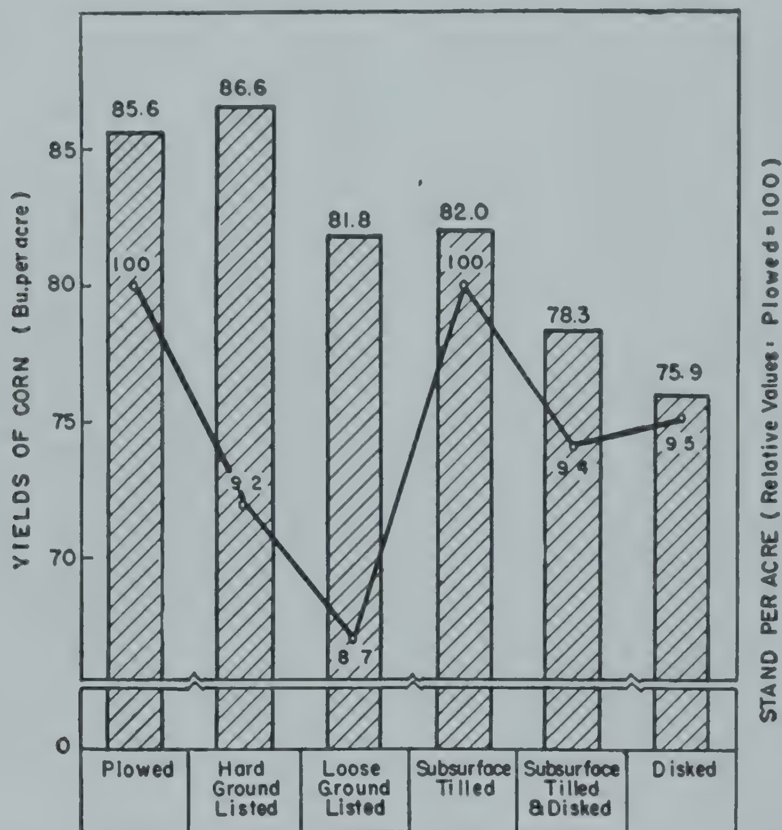


FIG. 17.—Effect of tillage methods on yield and stand of corn, Marshall silt loam, Clarinda, Iowa, 1944–1945. (*Courtesy of the Iowa Agricultural Experiment Station.*)

crop production. At the best, tillage operations are expensive; particularly is this true of such an operation as plowing. Any method that makes it possible to reduce these costs is of great importance to the farmer.

Methods of Seedbed Preparation.—The general methods of seedbed preparation involve the use of plows, listers, and disks as implements used in the initial operations. The plow has the advantage of turning under the plant residues such as stubble and thus hastening their decomposition. The plow in its various forms is the most widely used implement for the purpose of preparing for seeding. In the humid areas where it is common to follow a grass or legume crop with a cultivated

crop, it is necessary to break up the soil in such a manner that the plant material is covered. No other implement does this as well as the plow, although some modern machines do excellent work under most conditions.

The two common types of plow are the moldboard and the disk. The moldboard type shears off the furrow slice and inverts it so that the top of the slice is placed on the bottom of the furrow. The moldboard plows vary in width of furrow cut from 6 to 8 in. to as much as 6 ft. The most common types range from 7 to 18 in. and are single- or two-furrow horse-drawn walking plows, one- or two-furrow horse-drawn riding plows, or, as is more general on most farms, two- to fourteen-furrow tractor-drawn plows.

The disk plow is best suited to dry, hard soils or to sticky clay areas where the moldboard type does not work well. These plows, either horse or tractor drawn, range from one to eight or more disks.

In the drier sections it is common to use the lister, an implement that resembles a double plow with a right and a left bottom mounted back to back. These machines are often used to form ridges for the planting of crops that are bedded in rows. Sometimes the land is plowed and then ridged with the middlebuster. In drier areas the lister is used as a moisture-conserving device with the corn, sorghum, or small grain planted in the furrow to place the seed deeper in the soil and in contact with moisture. As the season advances the soil is worked into the furrow so that at the end of the tillage period the surface is level. Sometimes a basin-forming lister is used to form small dams at regular intervals in the furrow to hold water for the crop that is planted at the time of listing. The listers and middlebusters are made in various sizes from one to five rows and, according to the type, in furrow sizes from 8 to 14 in.

Throckmorton[1] presented an excellent report on the various methods of seedbed preparation on the Great Plains.

The so-called *stubble-mulch method* of preparing for winter wheat has met with much favor. With this method the soil is stirred so as to leave the stubble and trash on top of the surface. The plan has met with most success in those sections with limited rainfall. As Dean Throckmorton points out, the stubble method is not a panacea; it does have certain limitations and to be successful requires the use of proper implements in the hands of skilled operators.

Corn and Sorghums.—In nearly every case, corn and sorghums are

[1] THROCKMORTON, R. I., Plowless Farming on the Plains, *Country Gentleman*, May, 1946.

planted on land that has been plowed or listed. The Nebraska Agricultural Experiment Station[1] reported that for an average of 14 years listed corn yielded 21.3 bu. as compared with 17.7 bu. on land that was plowed and surface planted.

Salmon,[2] comparing listing and surface planting of corn in Kansas, found little difference in yields and concluded that listing was best for regions of limited rainfall and in areas of light soils was cheaper than surface planting.

In more recent work Kiesselbach *et al.*,[3] in a comparison of listed with surface-planted corn, found that the surface-planted corn yielded 2 per cent more than the listed corn. They indicated an advantage of the checked corn to be that it permits more efficient weed control.

TABLE 22.—EFFECT OF TIME OF SEEDBED PREPARATION ON THE QUANTITY OF AVAILABLE WATER IN THE SOIL AT WHEAT SEEDING TIME

Location	Number of years	Average inches of available water at seeding time		
		Late plowed	Early plowed	Fallowed
Hays	23	1.54	2.90	7.96
Colby	19	1.05	1.47	5.16
Garden City	13	0.44	1.08	4.67

In recent years there has been a tendency for listing to be used more extensively even in areas of adequate rainfall. Farmers maintain that it requires much less labor than the plowed land and surface-planted method. There are some dangers in the more humid areas in case of a wet season, as the water tends to collect in the listed furrows.

Winter Wheat.—Almost without exception winter wheat and rye are planted on land that is plowed in the summer or fall. The Kansas Agricultural Experiment Station[4] has shown the advantages of summer fallow for the storage of soil moisture. In long-time experiments at three locations in Kansas they found that fallow was essential as a means of stabilizing production in providing sufficient moisture at the time of seeding.

They reported that late seedbed preparation for wheat usually

[1] ZOOK, L. L., and W. W. BURR, Sixteen Years' Grain Production at the North Platte Substation, *Neb. Agr. Expt. Sta. Bull.* 193, 1923.

[2] SALMON, S. C., Corn Production in Kansas, *Kans. Agr. Expt. Sta. Bull.* 238, 1926.

[3] KIESSELBACH, T. A., ARTHUR ANDERSON, and W. E. LYNESS, Cultural Practices in Corn Production, *Neb. Agr. Expt. Sta. Bull.* 293, 1935.

[4] THROCKMORTON, R. I., and H. E. MYERS, Summer Fallow in Kansas, *Kans. Agr. Expt. Sta. Bull.* 293, 1941.

resulted in a low percentage of water available at seeding time and a correspondingly lower yield of grain.

Where soil moisture supplies are ample, as in the more humid sections, it may not be essential to plow early. Kansas reports that early plowing is necessary in the central and eastern sections of the state to aid in nitrate development. An important advantage, even under moist conditions, is that early plowing usually aids in better control of weedy plants.

TABLE 23.—AVERAGE YIELDS OF WHEAT, OATS, BARLEY, AND CORN ON SPRING-PLOWED AND ON FALL-PLOWED PLOTS AT DICKINSON, HETTINGER, AND WILLISTON, N. D., FOR THE PERIOD SPECIFIED

Station, years grown, and method	Wheat, bu.	Oats, bu.	Barley, bu.	Corn	
				Grain, bu.	Fodder, lb.
Dickinson, 1908–1923:					
Spring plowed	16.2	35.1	21.2	15.1	3,707
Fall plowed	16.5	33.5	20.4	15.1	3,277
Hettinger, 1912–1922:					
Spring plowed	11.6	29.0	21.0	....	6,004*
Fall plowed	10.5	25.6	20.6	....	6,344*
Williston, 1910–1920:					
Spring plowed	14.1	31.4	14.2	13.2	3,514
Fall plowed	13.9	28.2	12.7	13.8	3,542

* Corn yields at Hettinger are green weights as put into the silo, and averages are for the 9 years from 1914 to 1922.

Time of Plowing.—Many experiments have been made to determine the best time to plow land, with the most common studies comparing fall and spring plowing. Many farmers believe that the choice is largely a matter of convenience except under certain conditions. Where the land is subject to erosion, either by water or wind, spring plowing is usually most desirable. The longer the plowed surface is subjected to the erosion forces, the greater will be the probable losses. In rather complete trials in North Dakota it was shown that at Dickinson differences between fall and spring plowing were practically nil.[1] At Hettinger and Williston the results were slightly in favor of spring plowing except for corn, where there was some evidence in favor of fall plowing.

[1] MOOMAW, LEROY, Tillage and Rotation Experiments at Dickinson, Hettinger, and Williston, N. Dakota, *U.S. Dept. Agr. Bull.* 1293, 1925.

Under the more humid conditions of Minnesota, Arny[1] reported on various comparisons of disking and spring and fall plowing, over a 5-year period.

The land that was double-disked for oats and then spring-plowed for corn showed 6.6 bu. increase in corn production over the land that was fall-plowed. There was an advantage of 5.6 bu. in the oat yields in favor of spring plowing and a small advantage in hay yields.

In trials at three North Dakota stations where the plots were cropped continuously to wheat, oats, barley, and corn, there were no consistent differences between fall and spring plowing.

From Table 25 it would appear that yields were much the same whether the land was plowed in the fall or in the spring, as the small differences may be explained on the basis of chance variation. It is remarkable that the average yields are so nearly the same following the different treatments.

TABLE 24.—METHODS OF PREPARING THE SEEDBED

Method	Manure, tons	Yield per acre		
		Oats, bu.	Corn, bu.	Hay, tons
Double disk corn land for oats, spring plow for corn	6	63.8	57.2	3.0
Double disk corn land for oats, fall plow for corn	6	58.2	49.7	2.7

The seedbed that has been plowed in the fall has had time to settle and will require less time and labor to fit in the spring than the seedbed that was spring-plowed. Usually the fall-plowed land can be fitted by a shallow disking and thorough harrowing.

Spring-plowed land is likely to be loose and open to the depth of the plow sole. This land should be thoroughly disked and harrowed to encourage the knitting of the loose soil with the subsurface. Often it is necessary to roll or pack the soil to hasten the union of the loose soil with the firm areas below and to bring the seed into close contact with the soil. An extra disking or two may do much to encourage this. Some farmers use a weighted harrow or a heavy wooden planker. The best implement for securing a firm seedbed following the preliminary disking and harrowing is the cultipacker, an implement that firms the soil and leaves it in a succession of small ridges.

[1] ARNY, A. C., Crop Rotation Investigations, *Minn. Agr. Expt. Sta. Bull.* 170, 1917.

The disking of the stubble before plowing aids in the decomposition of the plant residues and yields a firm seedbed in a minimum of time, destroying many weeds before they produce seed, as it is possible to get over a large acreage with a disk within a short period. Frequently, it is not desirable to plow the land until late fall, and the disking offers a means of reducing weed-seed production.

Many farmers seed oats on corn stubble that has not been plowed but has been double disked to prepare the seedbed. Where the cornstalk growth is heavy it may be necessary to break the stalks with a stalk cutter or a heavy iron rail drawn across the field: Some farmers

TABLE 25.—AVERAGE YIELDS OF WHEAT, OATS, BARLEY, AND CORN CONTINUOUSLY CROPPED ON SPRING PLOWING AND FALL PLOWING, AT DICKINSON, HETTINGER, AND WILLISTON, N. D., FOR THE PERIODS SPECIFIED

Station, years grown, and method	Wheat, bu.	Oats, bu.	Barley, bu.	Corn*	
				Grain, bu.	Fodder lb.
Dickinson, 1908–1923:					
Spring plowed	12.7	27.5	21.4	16.9	3,343
Fall plowed	12.5	27.8	20.5	16.5	3,305
Hettinger, 1912–1922:					
Spring plowed	11.5	31.0	21.4	....	6,396
Fall plowed	8.9	31.1	20.7	....	7,021
Williston, 1910–1920:					
Spring plowed	12.1	23.2	13.0	15.8	4,947
Fall plowed	11.5	24.0	13.1	15.6	5,093

* Yields of corn at Hettinger are total wet weights as harvested for silage.

rake the cornstalks into piles and burn them. While this makes seeding easier, it is a waste as it destroys valuable organic matter needed on nearly all soils. If a farmer insists on burning the stalks, he should make certain to provide for their replacement through the addition of materials such as are secured from legumes in the rotation. Heavy applications of barnyard manure will also offset the loss of the cornstalks that are burned.

Fall-sown grain seedbeds are prepared in much the same manner as those for spring grains. Usually there is more time for seedbed preparation in the fall, and a better condition is likely to prevail. Many farmers disk the small grain stubble immediately after harvest and then plow later in the fall, while others plow immediately after harvest. In

more humid areas the land that is plowed immediately after harvest tends to become somewhat weedy before time to seed unless it is given an occasional cultivation with the disk or other implements.

Sewell[1] in a discussion of the seedbed preparation for wheat stated that in Kansas the difference in yield between July and September plowing averaged 10 to 14 bu. per acre in favor of the early plowing.

Under ordinary conditions the great demand for labor in the spring leads to much fall plowing, as this enables the farmer to get a considerable proportion of his work out of the way. There is some indication that fall plowing favors the control of certain types of insects, since they are exposed to injury from freezing as a result of being brought to the surface. In the case of the corn crop the time element is not so important as with spring-sown small grains. Usually there is plenty of time to plow in the spring and prepare a seedbed, while with the small grains early seeding is of great importance. A few days' delay in seeding may make a big difference in yield, especially in seasons when the summers are hot at the time the small grains come into flower. With the nearly universal use of the tractor the time element in seedbed preparation is not so important as was true in the days when all work was done with horses.

Depth of Plowing.—Every farmer appreciates the fact that the deeper he plows, the greater are his costs as a result of the increased power required to turn over the soil slice. It is generally accepted that varying the depth of plowing is desirable, since some types of soil tend to become packed at the plow sole if the same depth is followed year after year.

The purposes of plowing are to prepare a feeding zone for the plant roots and to incorporate organic matter, manures, or crop residues with the soil. This incorporation proceeds more rapidly with the turning under of the surface. Likewise, weedy plants or crop plants used as green manures are turned under to hasten their decomposition. Since the soil forms from the underlying parent material, frequently it is advisable to plow a little deeper to hasten the conversion of this raw material into the more productive soil.

Many experiments have been made to test the value of deep plowing. An excellent review of the early work on tillage has been made by Sewell.[2] He concluded from the available information that plowing

[1] Sewell, M. C., Wheat Seedbed Preparation (abstract), *J. Am. Soc. Agron.*, **17**: 644–645, 1925.

[2] Sewell, M. C., Tillage, A Review of the Literature, *J. Am. Soc. Agron.*, **11**: 269–290, 1919.

deeper than 7 in. has not usually given increased yields. Shallow plowing may be as productive as deeper plowing, but no definite conclusion can be drawn as to the best depth. In Kansas trials, for example, yields of corn and oats were higher on soil plowed 3 in. deep than on areas plowed to depths of 7 or 12 in. In more recent work in South Dakota, Hume[1] concluded that in central South Dakota greater total weights of corn were obtained from plowing 8 in. deep than from a shallower depth.

The best depth of plowing will vary with the soil type and the rainfall in any given area, and no definite rule can be applied to all sections. With the almost universal use of the tractor for power, the tendency has been to plow deeper than was generally true when the farmer was forced to depend upon the limited power of horses.

SEEDING OPERATIONS

The operations in seeding vary widely with the different crops. In general, however, such crops as corn and the sorghums are planted with a special planter or lister, while the small-grain crops are generally seeded with a grain drill or are sown broadcast.

Large operators are using considerable large-scale equipment to reduce labor costs. The large farm operators are now using the four-row corn planter, a tractor-operated machine that has greatly speeded the planting of large acreages. Most corn, however, is planted with a two-row planter. Most small grain is planted with a grain drill ranging from the small horse-drawn type to a large battery of two to eight tractor drills. In the corn belt considerable use is made of the endgate seeder, particularly for the seeding of oats.

Time of Seeding.—Earliness is a cardinal principle for the seeding of the spring grains. Most of the grains develop best under cool, moist conditions, and the earlier the planting date, the greater the opportunity to take advantage of the cool weather of spring and early summer. It is impossible to set dates for planting, since seasons vary so widely, but a good rule to follow is to plant spring wheat, oats, and flax as early in the spring as the land can be prepared, as a few days' delay in seeding may mean the difference between a good crop and a failure. In the spring of 1944 many farmers in the corn belt were unable to seed their grains until late. As a result numerous failures were recorded because the weeds offered much more competition and the crops were unable to

[1] Hume, A. N., Crop Yields as Related to Depth of Plowing, *S. D. Agr. Expt. Sta. Bull.* 369, 1943.

gain sufficient start to beat the coming of warmer weather. During the 6-year period of 1920–1925, Arny and Armour[1] report the results from five seedings of flax made at 10-day intervals, starting as early as the flax could be seeded. Delaying the seeding date by 10, 20, and 30 days resulted in yield decreases of 22, 33, and 47 per cent, respectively, as compared with the yields from seedings made at the earliest date.

FIG. 18.—Early seeding of spring grains is desirable. Oats on left were fully headed on June 20 while the variety on the right had not started to head. (*Courtesy of W. L. Burlison, Illinois Agricultural Experiment Station.*)

Early work at the Highmore, South Dakota, Station[2] shows that over a period of 8 years a Mar. 15 date was best for seeding spring wheat. The Mar. 1 date, the earliest used, gave a much lower yield. The yields obtained from Apr. 1 and Apr. 15 plantings were but little lower, showing a decrease of 1.4 and 2.0 bu., respectively. The May 1, seedings, however, dropped 8.6 bu. below the optimum date of Mar. 15. Comparable results were obtained with durum wheat with but little difference between the three dates, Mar. 15, Apr. 1, and Apr. 15. The Mar. 1 and

[1] ARNY, A. C., and M. L. ARMOUR, "Flax Production in Minnesota, Flax Facts," published by E. J. Mitchell, Minneapolis, Minn., 1944.

[2] HARDIES, E. W., and A. N. HUME, Wheat in South Dakota, *S. D. Agr. Expt. Sta. Bull.* 222, 1927.

May 1 seedings gave definitely lower yields. Similar results have been reported by other investigators, showing in general an advantage for early seeding.

It is usual to follow the wheat and flax seeding with barley and oats. In Kansas the best sequence is oats—flax. All the small grains are relatively resistant to cold injury, and usually they are not seriously injured by late frosts. At the Minnesota Station heavy frosts have been observed to do little or no damage to the young plants of early planted small grains.

With the fall-sown grains it is usual to delay seeding until after the Hessian fly free date, a problem that is considered in more detail in the chapter dealing with insects. North and west of the Hessian fly region, the fall grains are usually seeded during September when the moisture conditions are favorable. Here it is essential that seedings be made early enough to ensure a stand before the coming of cold weather. Exceedingly early seedings should be avoided in most areas as they result in the sacrifice of much moisture.

Methods of Seeding.—Many farmers of the corn belt do not own a grain drill and seed their oats by the broadcast method, with the end-gate seeder the common implement used. Many trials have been made to compare the drill with the broadcast method, and in general the yields on an average favor the use of the drill. Farmers using the broadcast method for oats maintain that the differences in yield are not great enough to warrant the use of the more expensive drill. Another argument is that often one can seed earlier with the broadcast method as the crop can be seeded when the soil would be too wet to operate a drill. Probably where only oats are grown in the rotation there is considerable justification in the use of the end-gate seeder. In some years the broadcast method yields more than the drill method because of its being possible to seed at an earlier date, a factor of great importance where oats follow corn and a considerable number of cornstalks remain in the field. With the generally higher valued wheat, barley, rye, and flax it will usually prove more profitable to seed with a drill. The drill that has a grass-seed attachment is of advantage in the seeding of the companion legume crop.

In some sections, winter grains are planted by the furrow method, a plan that places the seeds in small furrows, as it is believed that this provides a measure of winter protection. More advantage has been shown for the less hardy winter oats and barley than for winter wheat.

Kiesselbach and Lyness[1] in eastern Nebraska found that the furrow drill was inferior to the surface-drill method.

In general most farmers are using the surface method of planting. Very large drills are available for the large farms, and with a tractor many acres may be seeded in a day. The modern drills have attachments that permit the application of commercial fertilizers at the time of planting, a practice becoming more and more common as it is demonstrated that additional fertility is required for the most efficient production.

TABLE 26.—COMPARATIVE YIELDS FROM FURROW- AND SURFACE-DRILLED WINTER WHEAT, LINCOLN, NEB., 1930–1932

Manner of planting	Space between rows, in.	Average acre yield, bu.
Furrow drilled, narrow	12	34.0
Medium	14	35.3
Wide	14	33.5
Surface drilled, narrow	14	37.8
Narrow	7	42.1
Narrow	4	38.1

The sorghums and soybeans may be planted with the drill, or they may be seeded with a corn planter or lister. The method used will largely depend upon the use to be made of the crop. In general the sorghums and soybeans grown for grain are planted in spaced rows with a corn planter or lister. Corn is planted either with a corn planter or lister. A grain drill is rarely used, since the plant requires row cultivation for its best development, although some farmers close a number of the shoes and plant with a grain drill at any desired spacing.

Rates of Seeding.—No definite rule can be established for seeding rates as these vary with different sections of the country and for the most part are related to the rainfall of the section. Generally, the lighter rates of seeding are used in the regions of lowest rainfall. Some variations in rates are related to the use of the crop. For example, many farmers seed corn and sorghum for fodder or silage at a heavier rate than normally used when the crop is to be grown for grain. Every student of agriculture will find it necessary to become familiar with the rates of seeding found to be best by his own agricultural experiment

[1] KIESSELBACH, T. A., and W. E. LYNESS, Furrow versus Surface Planting Winter Wheat, *J. Am. Soc. Agron.*, **26**: 289–293, 1934.

station. However, it seems desirable to list the general rates of seeding for the important grain crops at the time of discussing the particular crops. Accordingly, rates will be given in later chapters under the specific chapters for each grain crop.

Every farmer should make certain of the calibration of his seeding machinery, as often the grain drill seeds at an uneven rate and variable stands result. It is a simple job to check the grain drill. Early in the

FIG. 19.—Thick seeding and close drilling (*left*) hasten ripening and reduce the height of the oat crop. Shorter plants on left were seeded at a 15-peck rate in 8-inch drill rows; the taller plants on the right were seeded at a $2\frac{1}{2}$-peck rate in 16-inch drill rows. (*Courtesy of W. L. Burlison, Illinois Agricultural Experiment Station.*)

season the drill is placed on a clean floor and the disks placed down so that the wheels can be turned freely. The drill box is partly filled with the grain to be seeded. Next, a mark is made on the rim of one of the wheels for purposes of checking the revolutions. The distance around the outside of the wheel rim is measured carefully. The boots of the drill are removed from the drill shoes and placed so that the grain falls on a canvas or into a container. Then by turning the wheel one is able to deliver the seed much as would be done in the field. If the drill is a 10-ft. drill, for example, turn the wheel until it has covered what would be comparable to a distance of 43.5 ft. This is done by computation of the wheel circumference. Collect the seed delivered during the turning of the wheel, weigh it in pounds, and multiply the weight by 100. The resulting figure will represent the approximate number of pounds of seed delivered per acre. It is well to check each half of the drill sep-

arately as the two sides of many drills will be found to vary in seeding rate.

The end-gate seeder may be checked by weighing into the hopper a given amount of seed. Drive a measured distance, remove the remaining seed from the hopper, weigh, and determine the amount of seed delivered. Multiply the width of the seeded area by the length to get the square feet, and on the basis of 43,560 sq. ft. in an acre it is simple to compute the rate of seeding.

The planting of corn, sorghums, and other seeds with a corn planter or lister may be checked by blocking up the planter wheels in a manner similar to that given for the grain drill. The introduction of hybrid corn has led to the use of various grades of corn, based on size and shape of kernels. Many seed dealers provide the necessary information as to the proper plates to use for their particular grades of corn, as this information is essential if one is to secure a uniform stand.

MAINTAINING SOIL FERTILITY

The grain crops are heavy users of plant food, particularly nitrogen, phosphorus, and potassium, as indicated in Chap. IV. This is not a disadvantage to the crops, but it does indicate that the continual removal will result in disaster if no effort is made to return the elements removed, as none but virgin soils permit the removal of crops without constant replenishment. Only in recent years have the farmers of the Middle West come to appreciate that they, like the eastern farmers, must add fertility to their soils if yields are to be maintained at a high level. Even when the crops are fed to livestock and the manure is returned to the land, the soil is gradually depleted and sooner or later will require the addition of supplementary fertilizer.

Types of Fertilizer.—In general there are two types of fertilizer, barnyard manure and commercial fertilizers. In addition there are the green manure crops and plant residues that may be turned under for soil enrichment.

Both the manures and the commercial fertilizers have a place on most farms In the drier sections of the country it is difficult to use manures, since they require considerable water for their decomposition. Many farmers use both types, supplementing the manure with the commercial fertilizer. The manure provides valuable organic matter which disappears rapidly from heavily cropped soils unless efforts are made to replace it.

Farm Manures.—Salter and Schollenberger[1] state:

One billion tons of manure, the annual product of livestock on American farms, is capable of producing $3,000,000,000 worth of increase in crops. The potential value of this agricultural resource is three times that of the nation's wheat crop and equivalent to $440 for each of the country's 6,800,000 farm operators. The crop nutrients it contains would cost more than six times as much as was expended for commercial fertilizers in 1936. Its organic matter content is double the amount of soil humus annually destroyed in growing the nation's grain and cotton crops.

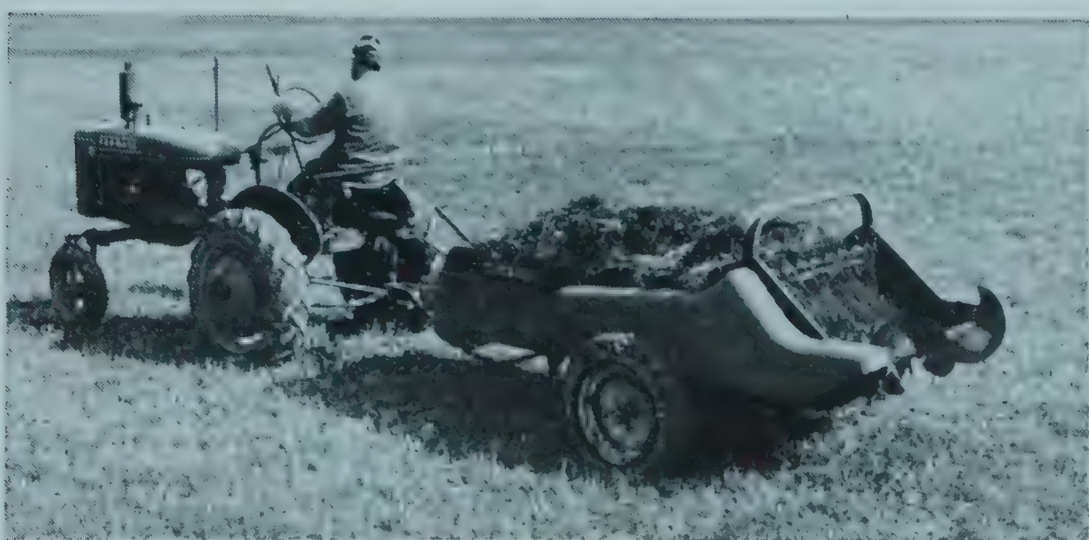


FIG. 20.—Barnyard manure is important in maintaining soil fertility. (*Courtesy of the International Harvester Company.*)

It is unfortunate that much of the value of this manure is lost. It is not uncommon to find heaps of manure rotting in barn lots with the greater part of its fertilizing value passing into the drainage waters or lost through the processes of fermentation. Except during the winter months when the ground is frozen it is desirable under most conditions to spread the manure as soon as possible after it is made.

Value of Manure.—The value of manure varies greatly, not only by class of livestock but the age of the animal and the type of feed that the animal receives. Salter and Schollenberger state that at the level of crop prices in 1937–1938 the average value of a ton of manure as fertilizer was $2.50. Over a period of years the value estimates range from $0.96 to $4.11 for general crops in Indiana and Iowa. They estimate that on the basis of $2.50 per ton, with a recovery of two-thirds

[1] SALTER, ROBERT M., and C. J. SCHOLLENBERGER, Farm Manure, "Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

of the potential manure production from feeding all crops except wheat grain, the annual value of the manure on 100 acres of land producing 50 bu. of corn, 40 bu. of oats, 25 bu. of wheat, and 2 tons of hay per acre in the rotation would be $500.

Compared with commercial fertilizers, manures do not rate high. An average figure for manure is 10 lb. of nitrogen, 5 lb. of phosphorus, and 10 lb. of potash per ton. This would mean that, roughly, a ton of manure would approximate a commercial fertilizer of 10-5-10. In addition, average manure contains considerable humus, an important factor in the maintenance of organic matter and one of the prime advantages of its use.

The value of manure depends to some extent on the type of litter used as bedding. The cereal straws are most widely used and are very satisfactory since they are cheap and fairly absorptive. Corn stover is rarely used as bedding and is less desirable than grain straw. Where the corn has been shredded, the less edible parts left by the animals serve fairly well, as the small pieces are capable of good absorption.

Manure in the Rotation.—Most farmers apply manure ahead of their main cash crop. In many cases this is corn, wheat, potatoes, or cotton. At the rate of 8 tons per acre for corn, some 200 lb. of plant food is added. If a farmer is able to make such an application at least once in the rotation, he will have done much to maintain his level of soil fertility. Those farmers who experience difficulty in getting a stand of legumes on light soils often find it advisable to apply the manure on the new seeding as a top dressing at rates of 2 to 4 tons per acre, applied either in the winter or immediately after spring plantings. If corn is grown 2 years in the rotation following a sod crop, it is best to apply manure ahead of the second corn crop. If corn and wheat are grown in the same rotation, it is common to apply the manure to the corn and use commercial fertilizer on the wheat. The place in the rotation to apply the manure is conditioned by several factors, but the one of major importance is to give the greatest advantage to the most profitable crop, which on many farms is a row crop such as corn. Manures generally cannot be applied ahead of barley or oats, as the available nitrogen is almost certain to cause severe lodging of the crop.

Commercial Fertilizers.—For most farmers the need for commercial fertilizers has become a reality. The question of whether to use fertilizers is a matter of simple arithmetic. The virgin soil contains a certain amount of plant nutrients; cropping practices remove a definite amount of nutrients each year; the difference between the amount that was in the soil at the start of the crop season and the amount that was

removed represents a decrease in total fertility. The use of legumes, manures, and crop residues aid greatly in slowing the rate of withdrawal, but ultimately the reserves are lowered until it is no longer profitable to crop the land unless fertility elements are added to the soil.

Determining the Need for Fertilizers.—It is possible to make an analysis of a soil and determine its content of plant nutrients. Such analyses have been made on many soils of the nation, and many farmers can secure

FIG. 21.—Tractor equipped with a front-mounted planter and a fertilizer attachment for placing fertilizer in row at time of planting. (*Courtesy the Allis-Chalmers Manufacturing Company.*)

reports of soil surveys made in their counties through their county agent or state agricultural experiment station. These reports provide valuable leads in that they indicate the general nature of the soils of the county and their probable fertilizer needs.

Probably the best means of determining the value of fertilizer on a farm is to learn the indicated needs and then make applications on a portion of the field, leaving an untreated part as a check. If the fertilizer is of value, it will be easy for the grower to determine its effect.

Types of Fertilizer.—In general, commercial fertilizers are classed as organic and inorganic. The organic fertilizers come from animal or vegetable products. They include such fertilizers as cottonseed meal, dried blood, fish scrap, garbage, tankage, sewage sludge, and linseed meal. The inorganic fertilizers usually come from mines where they

exist as raw materials. In recent years synthetic fertilizers have become of more and more importance. Inorganic fertilizers include the various nitrates, phosphates, sulfates, and chlorides. A fertilizer that contains nitrogen, phosphorus, and potash is known as a *complete fertilizer*. The quantity of each element in per cent is indicated in the order of nitrogen, phosphorus, and potash. A 10–12–5 fertilizer is a combination of 10 per cent nitrogen, 12 per cent available phosphoric acid, and 5 per cent water-soluble potash. Many farmers purchase single-element fertilizers such as the superphosphates, which carry only phosphoric acid. In these cases they depend upon manures or legumes for their nitrogen supply. The grain crops in particular require considerable phosphorus, and these fertilizers are used probably more extensively for grain production than any other type.

Lime is considered usually as a soil amendment, although it serves as a plant food in the same way as other elements. Many soils are acid in nature, *i.e.*, they have a pH value below 7.0. Such soils respond to applications of calcium, which are made usually in the form of calcium carbonate as ground limestone. Most of the legumes will not grow well on acid soils, and the addition of calcium has a direct relation to the grain crops, since the legumes are so essential to most rotations.

As the soils of the country age, it is evident that many are deficient in plant nutrients other than nitrogen, phosphorus, potash, and calcium. Some soils have shown the need for small applications of boron, while others are deficient in manganese, sulfur, or zinc. The problem of the need of minor or trace elements has opened a whole new field of investigation. The importance of these minor, as well as the more common, elements and plant indications of soil deficiencies have been thoroughly covered in a book edited by Hambidge.[1]

Methods of Applying Fertilizers.—The three general methods of applying fertilizers are (1) broadcast over the surface of the treated field, (2) placed in a localized area relatively near the seed or plant, and (3) placed in the furrow at the time of plowing.

The broadcast method involves the use of a spreader which places the fertilizer in closely spaced rows on or just below the soil surface. In some cases it is broadcast with a machine resembling an end-gate seeder, but this is less desirable than the spreader method. Lime is often applied with the broadcast machine, being delivered by truck from the lime crusher directly to the field.

In the hill or row application it is common to apply the fertilizer

[1] Hambidge, Gove, editor, "Hunger Signs in Crops," American Society of Agronomy and The National Fertilizer Association, Washington, D. C., 1941.

at the time of planting the crop, thus saving considerable labor. The object is to place the fertilizer near the seed, where it may be available to stimulate the growth of the young plant. The localized treatment results in more complete use of the nutrients by the immediate crop than in the broadcast method. With hilled crops, as corn and the sorghums, a special attachment makes it possible to drop a small quantity of fertilizer at the time the seed is dropped.

In recent years there has been considerable experimentation with the application of the fertilizer at the time of plowing the land. With this system the fertilizer is dropped at the bottom of the furrow to become available when the young plant develops its feeding roots in that region. There is considerable evidence to favor a combination of row application with the furrow method. The row application stimulates quick, early growth, while the nutrients in the furrow provide for continued development as the plant grows.

Fertilizers for Corn and Sorghums.—Salter[1] recommends hill or row application of fertilizers for corn. Checked corn should have the fertilizer placed in the hill, preferably in two bands 6 to 8 in. long on each side of the seed and separated from it by ½ to 1 in. of fertilizer-free soil. The bands may be 1 in. wide for quantities of fertilizer up to 200 lb. per acre. If the corn is drilled, the bands are continuous on either side of the seed. The treatment for grain sorghums is much the same as for corn.

Fertilizers for Small Grains.—It is common to use a fertilizer attachment on the grain drill and place the fertilizer close to and in partial contact with the seed. Even though some injury occurs, this is offset since many seeds are planted and extensive stooling usually takes place.

Fertilizers for Soybeans.—The soybean is sensitive to fertilizer injury, so the fertilizer must not come in contact with the seed. If the seed is drilled it is desirable to broadcast or drill the fertilizer in a separate operation. If the seed is planted with a corn planter the side-band fertilizer distributor may be successfully used.

CULTIVATION

The primary reason for cultivation is to destroy weedy plants. The undesired plants compete with the crop plants for food, water, and air. Since two species of plants cannot occupy the same area without competition, it is evident that the weedier the land, the greater will be the competition. So it is general to plant many of our crops in rows to

[1] SALTER, ROBERT M., Methods of Applying Fertilizers, "Soils and Men," *U.S. Dept. of Agr., Yearbook of Agriculture,* 1938.

permit tillage with special implements. Many crops, such as the small grains, are not grown in cultivated rows. In the case of these crops it is planned to control the weeds by means of tillage of the other crops in the rotation and at the time of preparing the seedbed. Other reasons for tillage are to prepare a satisfactory seedbed, to improve the physical structure of the soil, and to aid in the control of certain insects and diseases.

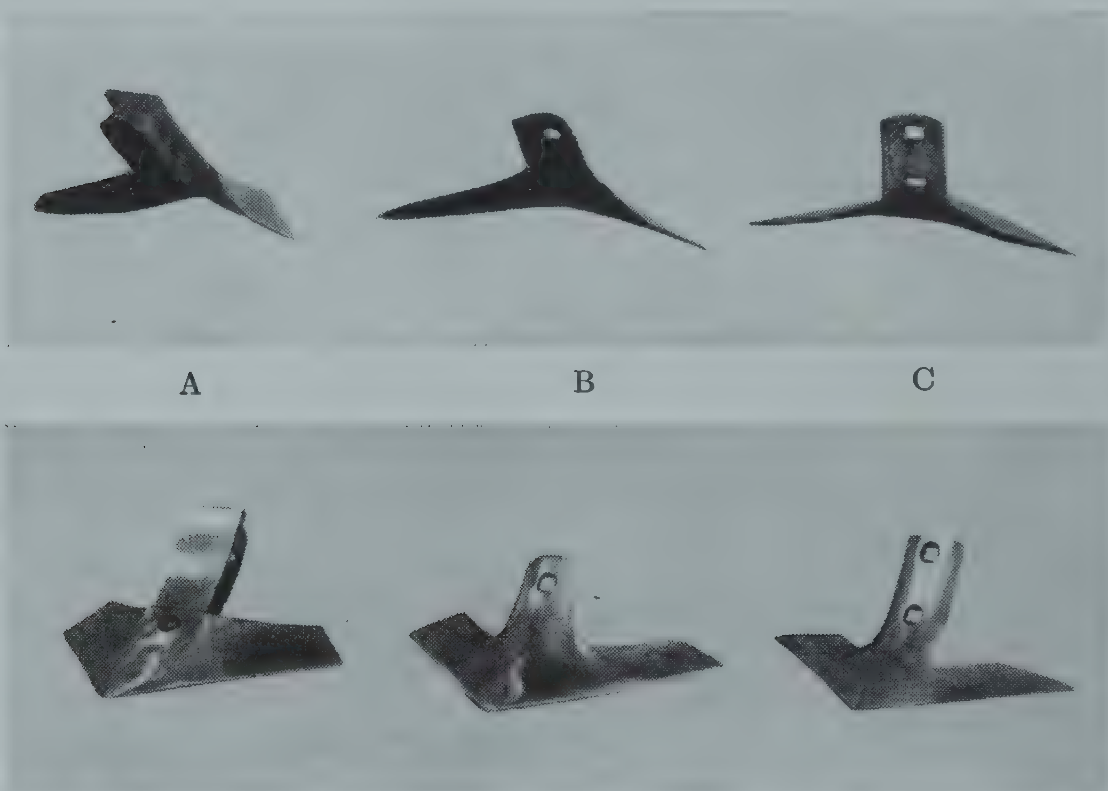


FIG. 22.—High-, medium-, and low-pitch cultivator sweeps (*rear view, top; front view, bottom*). The high-pitch sweep at the left will throw more soil into the corn row to cover weeds but leaves more of a furrow than the low-pitch sweep shown at the right. (*Courtesy of C. K. Shedd, Iowa Agricultural Experiment Station.*)

The preliminary work of disking and harrowing after the land has been plowed may be classed as tillage operations. The soil is loosened, the clods are crushed and firmed, and the soil is placed in the proper condition for seeding. These operations at the same time improve the physical condition of the soil, as preparation of the seedbed involves its physical improvement. Under some soil conditions the surface tends to become hard and baked during dry weather, so that tillage may be necessary although no weeds are present.

Time to Cultivate.—This is dependent upon several environmental factors. With most soils it is undesirable to cultivate when the soil is

wet as this may cause it to become hard and lumpy. Likewise, tillage of very dry soil may result in the formation of large lumps that are difficult to reduce to a fine state.

In humid sections one must gauge the tillage operations in relation to rainfall. As stated earlier, it is unwise to plow in the fall in areas subject to erosion.

Frequency of Tillage.—In the tillage of row crops, farmers plan to cultivate often enough to destroy the weeds. Usually this will be three

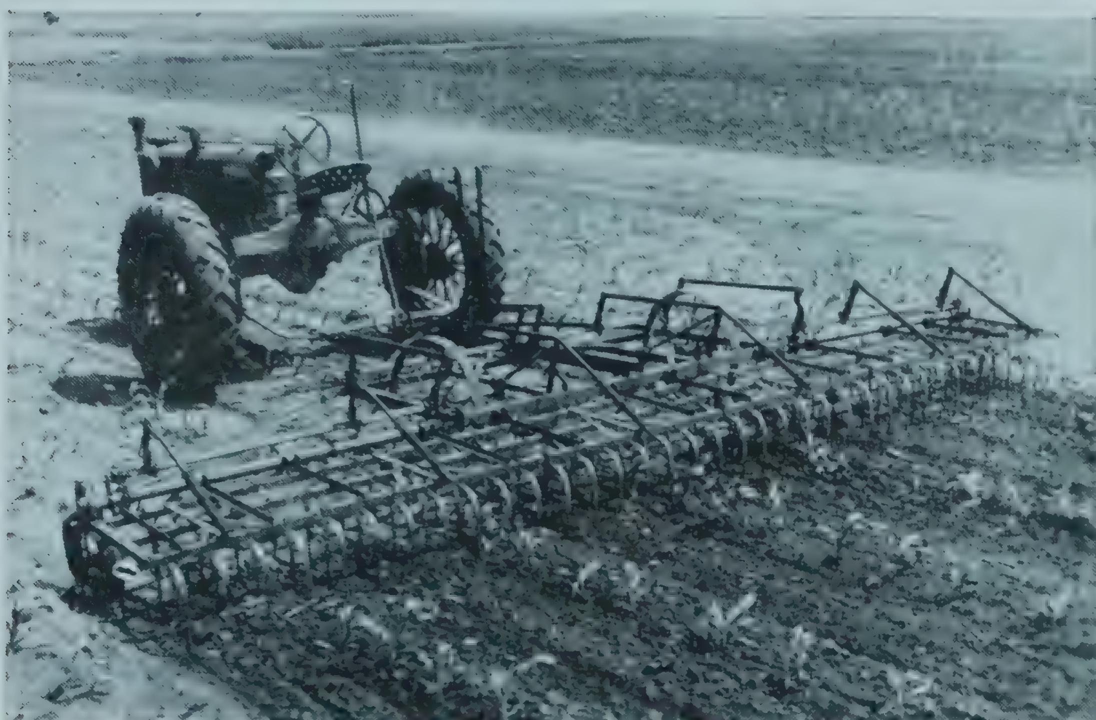


FIG. 23.—The spring-tooth weeder in a six-row width is suited to destroying weed seedlings with little labor. (*Courtesy of C. K. Shedd, Iowa Agricultural Experiment Station.*)

to four times on check-rowed crops. This operation is usually done with a tractor-drawn cultivator, which enables the operator to cover a large area within a short time. Extra tillage with the harrow when the plants are small is economical and effective if done at the proper time. In harrowing plants it is well to do the work in the afternoon when the plants are not succulent and thus more likely to break.

Cole and Mathews[1] state that the soil mulch has little effect in preventing the escape of water but that the cultivation that creates the mulch destroys the weeds that would use the water.

[1] COLE, JOHN S., and O. R. MATHEWS, Tillage, "Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

Cultivation Machinery.—The common shovel cultivator is widely used, ranging in size from the one-horse type up to the four-row, tractor-drawn machine. It is desirable that flat-surfaced blades be used on these cultivators after the row crops have become large enough to form a mass of roots near the soil surface and between the rows.

The rotary hoe, a machine fitted with a series of 18-in. hoe wheels equipped with radially projecting fingers, is a valuable machine for the early cultivation of row crops.

Several types of weeders are available and are valuable in destroying young weeds with a minimum of labor. It is probable that the spike-tooth harrow may accomplish much the same purpose and thus obviate the purchase of an additional implement.

The spring-tooth harrow is valuable in the cultivation of stony or stumpy areas. It also serves to drag out the roots of quack grass and is used in infested areas as an important weed tool.

THE CONTROL OF EROSION

The farmer is confronted with two general types of erosion: wind erosion and water erosion; but fortunately not every region is subject to both types. Wind erosion is most prevalent in the relatively dry areas where there is insufficient moisture to prevent the soil from drying to the point that will permit it to be moved by the wind. Even in more humid areas a dry period with strong winds may cause considerable soil movement. In some sections it is undesirable to plow land in the fall because the open, snowless winters may bring about much soil blowing. As with dry soil, the light or sandy soil moves readily during windy periods. These soils are often found in humid areas, but because of their nature they are unable to hold enough moisture to prevent their drifting with the wind. Under extreme conditions such soils may drift with the wind and in some cases form dunes, with the resulting elimination of the land for agricultural purposes.

Water Erosion.—The loss of valuable soil by water erosion occurs wherever there is sufficient rainfall to cause the movement of water. This means that nearly all agricultural land is subject to erosion. Fortunately, it may be controlled through proper management, but as a rule the losses are great. According to Bennett and Lowdermilk,[1] "water and wind erosion remove not less than 3 billion tons of soil from the croplands and associated pastures of the nation every year. Some 730,000,000 tons of solid matter are carried annually into the Gulf of

[1] Bennett, Hugh H., and W. C. Lowdermilk, General Aspects of the Soil Erosion Problems, "Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

Mexico by the Mississippi River alone." The same authors state that the 3 billion tons of soil represent some 43 million tons of phosphorus, potassium, and nitrogen. The amount of fertilizer carried away is more than sixty times the amount of the three elements listed as being used in the United States as commercial fertilizer during the fiscal year ending June 30, 1934.

The raising of grain crops by the nature of their growth tends to lead to increased soil erosion, especially with crops that are grown in cultivated rows, such as corn and sorghums. This does not lead to the

Fig. 24.—Contour strips with oats in the foreground, an alfalfa strip on each side, and corn on the uppermost strip in the background. Strips are 75 to 85 feet in width and the slope is 10 to 12 per cent. (*Courtesy of the U.S. Soil Conservation Service.*)

conclusion that the farmer should not grow grain crops, but rather that he should modify his practices to enable him to check erosion while the crops are being grown. There are many areas where grains are being grown that should not be cultivated because of their steep slopes. Much of this land should be kept in permanent pasture crops so that the soil may be saved, and in some cases reforestation is probably the best solution.

Strip Cropping.—The use of strip cropping makes it possible to farm slopes where erosion is likely to occur, as the strips break the length of the slope and thus check the rapid movement of the water with its resultant destructive action.

The contour-strip crop plan provides for farming on the contour. This frequently gives a serpentine type of strip, a condition that appears

undesirable to the farmer who has never practiced it. However, when once placed in operation, most farmers find the contour-strip crop thoroughly satisfactory. One primary disadvantage is that it is somewhat more difficult to control weeds since it is usually impractical to check plant the row crops.

The strip-crop system may be set up with little extra labor. Usually it is possible for a farmer to get assistance from his local soil-conservation representatives, county agent, or state agricultural experiment station. Placing the rows on the contour means long, narrow fields that in some respects save time since less turning is required. Another great advantage lies in the fact that farm operations are on the level, and considerably less power is required than would be necessary under the plan of going up and down the slopes.

The width of the strip crop will vary with the slope of the land, the steeper the slope, the narrower will be the strip. According to Kell,[1] under the most favorable conditions strips should rarely, if ever, be wider than 200 ft., and it is impractical to have them less than 50 ft. wide.

The strip-crop plan should tie into a rotation scheme that makes it possible to alternate meadow strips with the cultivated ones. Unless this is done the effectiveness of the plan will be lost. Under severe erosion conditions it may be desirable to keep certain areas more or less permanently seeded to perennial crops.

Terraces.—Generally the terrace is used on the slope that is too steep for strip cropping to be very effective. Often the two systems are combined to advantage. The making of terraces requires considerably more skill and is much more expensive than the setting up of strip cropping. It is important that a careful check be made to determine the degree of slope and the best means of its correction.

The two principal types of terrace are the absorption type and the drainage type.[2] The absorption terrace is a ridge designed to hold the surplus water until it can be absorbed. The drainage terrace provides a channel for the water, with the channel level at the upper part of the slope and, or nearly so, gradually increasing in grade along its length to provide for the increased capacity without change in width. The channel must be so arranged that the water cannot gain erosive velocity but is slowly carried to the lower levels.

[1] KELL, WALTER V., Strip Cropping, "Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

[2] NICHOLS, M. L., and T. B. CHAMBERS, Mechanical Measures of Erosion Controls, "Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

Kell and Brown[1] have outlined in detail the place of the strip-cropping plan and the use of the terrace in soil conservation. Also they discuss the various problems in the use of erosion control as related to the management practices from the viewpoint of the farmer.

Wind Erosion.—This is primarily a problem of the Plains Area, although it may occur in almost any section where conditions are favorable to the drifting of the soil. Much publicity has been given to the

FIG. 25.—Field drainage runoff in terrace during 3-inch rain on 4 per cent slope. (*Courtesy of Donald E. Wolfe, U.S. Soil Conservation Service, Mt. Pleasant, Iowa.*)

effects of wind erosion, particularly as it occurred in the section known as the *dust bowl.*

In the central Great Plains area, where wind erosion has been of so much importance, Call[2] has given certain rules to prevent disastrous wind erosion.

1. Keep the soil covered with growing vegetation or crop residue as much of the time as possible, consistent with good soil and crop management.
2. Avoid as far as possible working the soil when it is dry.
3. Take precautionary cultural measures to protect the soil against wind erosion before it occurs, and if blowing starts take prompt action to stop it.

[1] KELL, WALTER V., and GROVER F. BROWN, Strip Cropping for Soil Conservation, *U.S. Dept. Agr. Farmers' Bull.* 1776, 1937.

[2] CALL, L. E., Cultural Methods of Controlling Wind Erosion, *J. Am. Soc. Agron.*, **28**: 193–201, 1936.

4. Restrict cultivation for the control of wind erosion to the amount needed to obtain the necessary control.

5. Use implements for cultivation of a type that leave the surface soil rough and ridged rather than smooth and level.

6. Take advantage of any rains that fall to cultivate the soil in a manner to hold it from blowing until a growth of vegetation starts to protect the soil.

FIG. 26.—The use of crops planted crosswise to the direction of the prevailing winds protects the soil by reducing the velocity of surface winds. (*Courtesy of the U.S. Soil Conservation Service.*)

7. Reestablish permanent vegetation on areas of soil so sandy, so arid, or so impervious to water that the control of wind erosion is extremely difficult. Such areas constitute but a small portion of the cultivated lands in the central Great Plains.

Many farmers on light, sandy soils encounter a serious erosion problem in the early part of the growing season when the shifting sand particles may cut off the young plants. In these areas it is common to plow or list alternate strips as soon after a rain as possible so as to provide a rough surface that will check the movement of the wind. The use of the lister aids in the control of wind erosion, since the furrows break the wind's force and the plants are protected.

The proper use of crops will do much to control wind erosion in many cases. Thorfinnson[1] recommends the use of brome grass and

[1] THORFINNSON, M. A., Wind Erosion Control, *Minn. Agr. Ext. Bull.* 235, 1942.

alfalfa and of crested wheat grass and timothy for the binding of soil subject to wind erosion.

As in the control of water erosion, strip cropping may be used to prevent wind erosion. The grass strips check the rate of wind movement and decrease the rate of evaporation from the bare strips. The direction of the strips should be at right angles to the prevailing winds so as to offer the least bare surface to a direct sweep of the wind. In practice it is more common to use alternate strips of crop and fallow.

HARVESTING

Harvesting, the same as other phases of farming, has undergone a revolution during recent years. The change from the cradle to the self-binding reaper marked a great advance in agriculture and made possible an enormous expansion in grain production. No less important has been the shift from binder harvest to the use of the combine harvester thresher. The number of acres of grain that can be farmed per man is much greater today than was true a few years ago, and this has made it possible for farmers to maintain a high level of production in spite of serious shortages of manpower.

The successful farmer plans to harvest his crops just as early as possible, but not before the crop is mature enough to give maximum yields of superior quality. If wheat is cut too early, the grain may be shriveled and the quality be inferior. Too early harvesting with the combine may result in heating of the grain in storage. If it is left too long, shattering losses may occur, the plants may lodge, or the grain may be bleached, all factors that will mean losses to the grower.

It is a common belief among some farmers that small-grain crops heavily attacked by rust should be harvested before they mature to secure the best yields. Wilson and Raleigh[1] have shown this to be incorrect. Grain plants continue to develop their seeds as long as the plant has a water content of more than 40 per cent. Rust may slow the maturity rate of the grain plants, but even under these conditions it is better to delay harvest until the normal time.

Grain that is harvested with a binder or is windrowed for combining may be cut somewhat earlier than that which is combined directly. The farmer who has large acreages may feel it necessary to start harvest as early as possible in order to complete the job within a reasonable period. It is best, however, to delay the start of harvest until the grain

[1] Wilson, H. K., and S. M. Raleigh, Effect of Harvesting Wheat and Oats at Different Stages of Maturity, *J. Am. Soc. Agron.*, 21: 1057–1078, 1929.

is in the dough stage. At this time no further materials are being elaborated, and ripening is a matter of water loss. Care must be taken to avoid spoilage from the high water content of the straw if the crop is cut with a binder and shocked. Some varieties, such as Vicland and Tama oats, tend to have green straw after the grain is ripe enough for harvest, and care must be exercised to prevent spoilage in the shock.

When grain is harvested with a binder, it often contains 20 to 30 per cent water. Naturally such grain must be dried before threshing. Usually the drying process is completed in the shocks formed from the bundles. Many farmers thresh the bundles from the shock. Others choose to stack the bundles and thresh at their leisure. With the increase in the number of small threshing units, there has been less tendency to thresh from the stack.

The combine is now used in many humid areas where it was once believed totally unsuited. Since grain should have a water content of not more than 14 per cent for safe storage, it is evident that the grower must delay harvest until this stage of ripening if he is to combine standing grain. However, in the more humid areas he does not let the grain stand but cuts it and leaves it in a windrow or swath to dry. This also permits the drying of the green weed plants, which may be a problem even in ripe grain. As soon as the grain has dried in the swath it is threshed with a combine equipped with a pick-up device that gathers the grain from the stubble and delivers it onto the combine platform.

Much labor is saved when the combine is used, as one man may do the work of several using the older methods. A big disadvantage of the combine in areas where straw is valued for bedding is that it may mean the loss of the straw. It is possible to bunch the straw and collect and bale it after the combine, but it is not so desirable as the straw obtained from binder harvest.

Corn is harvested for grain when it is well matured. Commonly this will be after frost, with the coming of cold weather. If the weather is cool it is usually safe to crib corn when the water content of the grain has been reduced to 25 per cent. Not all corn matures within the available growing season and so-called *soft* corn frequently occurs. Such corn is often placed in the silo or fed to livestock as rapidly as possible. Since it is immature, it is of lower feeding value than corn that has completed its normal development.

Corn for silage does not need to be fully matured. Many farmers prefer to ensile corn when the ears are in the dent stage and the stalks are green with their leaves attached. It is desirable to harvest silage

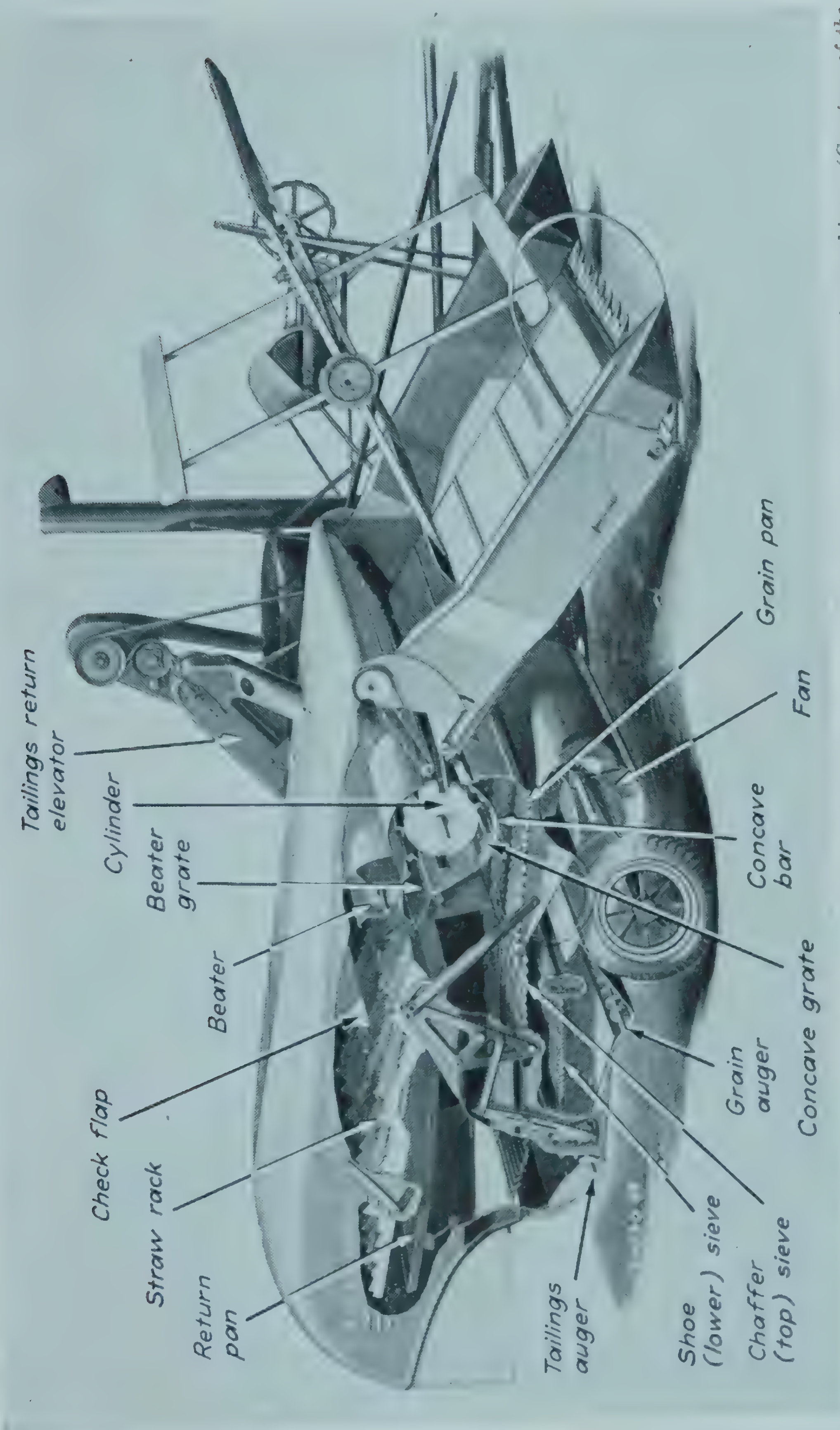


FIG. 27.—Cross-sectional view of a typical combine, showing arrangement of the various units inside the machine. (Courtesy of the Missouri Agricultural Experiment Station.)

corn before frost to avoid the loss of leaves. Immature late corn may be ensiled to good advantage if the farmer has uses for the silage.

In many sections of the country corn is harvested with a corn binder or by hand and placed in the shock to dry. It is common to cut this corn when it is well dented and if possible before frost to save the leaves, as many farmers feed the bundle fodder to their stock during the winter months. In many parts of the East it is common to husk the ears from the shocked plants and then rebuild the shocks for later feeding to livestock. Some growers haul the shocks to the barn where they are passed through the shredder which husks the ears and shreds the stalks into fine pieces. The shredder is not so widely used as was common a few years ago.

Grain sorghums are harvested much the same as corn. The crop may be harvested when the seeds have hardened, shocked, and threshed when dry. The combine types are harvested when the grain contains not more than 14 per cent water. It is common to cut the heads from the plants, pile them in stacks to dry, and thresh with a threshing machine. The grain types are not so desirable for silage as the sweet sorghums since the stalks are dry and less palatable.

STORAGE OF GRAIN

The farmer who produces considerable grain is confronted with the numerous problems of storage. Unless the grain is hauled from the thresher to the elevator, it must be placed in bins that will protect it from the weather as well as from rodent and insect injury.

Small grains should be dried to 14 per cent or less moisture before they are placed in storage. If they are stored with a higher water content, heating is almost certain to occur, with resulting damage to the grain. Bins may be made of wood or metal, depending upon convenience and availability of materials. Above all, they should be thoroughly tight, and if possible mouse- and ratproof. If the bin is large it is desirable to provide for some means of ventilation.

Ear corn may be stored with as much as 25 per cent water if the weather is cool and drying conditions are favorable. If corn with more water is stored, it is desirable to provide air ducts through the crib. In extreme cases warm air may be driven through by the use of a hot-air furnace and fans. This method usually is not practical except where seed corn is being stored.

Probably no other crop is stored under such a variety of conditions as corn. The slatted-siding, tall, narrow crib is a desirable type. The

picket-fence crib is not so desirable but is widely used. The principle objection to these cribs is the great losses that occur from weather and rodent damage. It is not uncommon for the losses from such cribs to run as high as 5 to 10 per cent of the corn stored. If the storage is temporary these cribs may be desirable, but too often the grain is left there throughout the winter and spring seasons.

MARKETING

The farmer has two methods of disposing of his grain: (1) selling the grain or (2) feeding to livestock. The choice of method will depend upon many factors, such as the type of crop, location, size of farm, and markets. Naturally the big wheat farmer will expect to market his grain and not to feed it. The producer of flax and soybeans for oil will plan to sell the seed to the processor. To a large extent many of the other grains find their way to the market.

In many areas, especially where hogs and cattle are fed, much of the grain will be fed on the farm. This is believed by the livestock producer to be an economical way to market his grain. Instead of making several trips to the elevator to dispose of his crop, he may move his feed in the converted form of livestock with a minimum of labor. In addition, the manure from the feeding operations is made available for return to the fields to aid in the maintenance of soil fertility.

The best time to market grain is a never-ending problem of the farmer. Like all other commodities, prices are based upon supply and demand. Frequently at harvest time so much grain is being moved to market that prices are depressed, and some growers prefer to store their grain so as to move it to market after the rush period. Such a procedure is not always possible or desirable. The farmer who markets most successfully is the one who studies the market reports so that he may be informed as to the probable supply of grain and its relationship to the demand.

All grain sold in the terminal markets is graded according to United States standards.[1] These standards make it possible for the farmer who produces superior quality grain to gain a reward for his product. For example, the farmer who sells oats with a bushel weight of 34 lb. should expect a better market price than is offered for oats weighing 32 lb. The entire program on a given farm should be directed to culminate in the production of a superior product that demands a premium

[1] "Handbook of Official Grain Standards of the United States," *U.S. Dept. Agr., U.S.G.S.A. Form* 90, 1941.

on the market. Frequently the added quality may mean the difference between profit and loss from the enterprise. Only the informed farmer can hope to gain the most from the marketing of his products.

The problems of marketing as they concern the producer of grains are considered in more detail in Chap. XXII.

Review Questions

1. What is meant by young soils and old soils?
2. What is a virgin soil?
3. Why are prairie soils inherently fertile?
4. What types of soils are best suited for corn production?
5. How are fertilizers applied to grain crops?
6. How is soil type related to the high quality of hard red spring and hard red winter wheats?
7. Why is so much rye grown on sandy soils?
8. What are the advantages to the farmer of recleaning his seed grain?
9. Explain how the farmer might profit from the weed seeds separated from grain.
10. Outline the principles of good seedbed preparation.
11. Why is it generally considered desirable to plow land in preparing a seedbed?
12. When would you advise the use of a lister?
13. What are the common methods of preparing a seedbed for oats in the corn belt?
14. When would you advise the use of the grain drill?
15. When would it be advisable to seed broadcast?
16. What factors determine the proper depth to plow?
17. Explain how the use of large-scale machinery such as a four-row corn planter has increased the number of acres operated per man.
18. Why is early seeding of spring grains desirable?
19. What are the principal advantages of the end-gate seeder?
20. Explain how one would calibrate a drill.
21. Make a map of your home farm, and set up a program for maintaining and improving fertility.
22. Why does the average farmer lose so much of the value of barnyard manure?
23. How can one determine the fertilizer needs of his soil?
24. How does an organic fertilizer differ from an inorganic one?
25. Why do we cultivate crops?
26. How often should one cultivate?
27. How can the spike-tooth harrow be used as a weeder?
28. What are the types of erosion?
29. Give illustrations of erosion observed in your community.
30. How are grain crops related to erosion problems?
31. What are the advantages of strip cropping?
32. When would you advise the use of a terrace?
33. How can one control wind erosion?
34. Does it pay to harvest rusted grain before maturity? Why?
35. What are the advantages of windrowing grain rather than combining directly from mature grain?

36. When should corn be ensiled?

37. At what moisture level is it safe to store small grains? Corn?

38. What factors determine whether a farmer will market his grain for cash or feed it to livestock?

References

ANONYMOUS: Does Soil Conservation Pay? *Wis. Agr. Expt. Sta. Bull.* 459, 1943.

BEESON, KENNETH, C.: The Mineral Composition of Crops with Particular Reference to the Soils in Which They Were Grown, *U.S. Dept. Agr. Misc. Pub.* 369, 1941.

CARTER, L. S., and G. R. MCDOLE: Stubble-mulch Farming for Soil Defense, *U.S. Dept. Agr. Farmers' Bull.* 1917, 1942.

COLE, JOHN S., and O. R. MATHEWS: Tillage, "Soils and Men," *U.S. Dept. Agr., Yearbook of Agriculture*, 1938.

CONREY, G. W., J. S. CUTLER, and A. H. PASCHALL: Soil Erosion in Ohio, *Ohio Agr. Expt. Sta. Bull.* 589, 1937.

COX, J. F., and L. E. JACKSON: "Crop Management and Soil Conservation," John Wiley & Sons, Inc., New York, 1937.

———, and ———: "Field Crops and Land Use," John Wiley & Sons, Inc., New York, 1942.

DETURK, E. E.: The Problem of Phosphate Fertilizers, *Ill. Agr. Expt. Sta. Bull.* 484, 1942.

GUSTAFSON, A. F.: "Soils and Soil Management," McGraw-Hill Book Company, Inc., New York, 1941.

———, C. H. GUISE, W. I. HAMILTON, and H. RIES: "Conservation in the United States," 2d ed., Comstock Publishing Company, Inc., Ithaca, N. Y., 1944.

HAYS, O. E., and N. CLARK: Cropping Systems That Help Control Erosion, *Wis. Agr. Expt. Sta. Bull.* 452, 1941.

HUGHES, H. D., and E. R. HENSON: "Crop Production," The Macmillan Company, New York, 1930.

HUTCHESON, T. B., T. K. WOLFE, and M. S. KIPPS: "The Production of Field Crops," McGraw-Hill Book Company, Inc., New York, 1936.

JONES, M. M., and R. P. BEASLEY: Combine Harvesters in Missouri, *Mo. Agr. Expt. Sta. Bull.* 436, 1941.

———, and ———: Corn Tillage Studies on Rolling Putnam Silt Loam, *Mo. Agr. Expt. Sta. Bull.* 475, 1943.

KELL, W. V., and ROLAND MCKEE: Cover Crops for Soil Conservation, *U.S. Dept. Agr. Farmers' Bull.* 1758, 1936.

LUCAS, R. E., G. D. SCARSETH, and D. H. SIELING: Soil Fertility Level as It Influences Plant Nutrient Composition and Consumption, *Purdue Univ. Expt. Sta. Bull.* 468, 1942.

CHAPTER VI

WEEDS

The plants commonly known as weeds cause great losses in the grain fields of the United States each year. They are so universally present and exist in so many different species that their very universality tends to lead the average person to fail to realize their extreme seriousness. Many farmers take weeds for granted and accept them as necessary evils without giving sufficient consideration to the need for their prevention and control. This cannot help but be true. If it is not true, how can one explain the very common practice of planting seed that is badly infested with a variety of weed seeds? This indifference and carelessness is responsible for the initiating of many new infestations of undesirable weeds each year. Until an appreciation of the importance of weeds and their control is more universally prevalent, it will be extremely difficult to secure adequate control.

DEFINITION OF A WEED

Various definitions have been given for a weed. One of the simplest and rather effective definitions is the following: "A weed is a plant out of place." In other words, any plant that is growing where it is not desired takes on the attributes of a weed. For example, sweet clover or alfalfa growing in a corn field will interfere with the growth of the corn through the use of available water and plant food and therefore must be considered as weed plants. If a farmer were to plant soybeans with his corn, the soybeans would not be classed as weeds since they are grown for a definite purpose. If the soybeans are growing spontaneously in the corn and the farmer wishes to eliminate them, they are weeds. Pieters[1] has defined a weed as "a plant that does more harm than good and has the habit of intruding where not wanted." This definition would not fit the examples above, as the volunteer soybeans could scarcely be considered as having the habit of intruding where they are not wanted. Georgia[2] has defined a weed as a plant growing where it is desired that something else shall grow. It would seem that this

[1] PIETERS, A. J., What Is a Weed? *J. Am. Soc. Agron.*, **27**: 781–783, 1935.

[2] GEORGIA, ADA, "A Manual of Weeds," The Macmillan Company, New York, 1914.

definition is inclusive enough to cover all conditions and should be generally satisfactory.

IMPORTANCE OF WEEDS

Weedy plants probably cause greater losses to the American farmer than any other hazard with which he must contend. The Agricultural Service Department Committee of the United States Chamber of Commerce has estimated the annual losses from weeds in comparison with other agricultural pests as follows:

Diseases of livestock (not including deaths from eating poisonous plants)	$ 250,000,000
Plant diseases (10 leading crops plus forest trees)	1,190,000,000
Insect pests of plants and animals	1,125,000,000
Weeds	3,000,000,000

The above data indicate that weeds cause greater losses to the American farmer than all the other hazards combined. Yet how generally is this realized? Consider how much greater concern arises from an outbreak of grasshoppers than would be displayed at sudden report that field bindweed has been introduced into a county. The former story would make the front pages of the newspapers, while a story regarding the bindweed infestation would not gain a line of space. Yet, the introduction of the bindweed into a new area would probably prove much more costly than the damage by the grasshoppers. The grasshopper injury might be limited to one season, while the new weed may persist for years and continually spread to other farms in the section.

FIG. 28.—Field bindweed in a grain field. (*Courtesy of L. W. Kephart, U.S. Department of Agriculture.*)

CLASSES OF WEEDS

Weedy plants may be classified in several categories. From a botanical viewpoint they are classified as to length of life into annuals, winter

annuals, biennials, and perennials. As might be expected, in general the perennial weeds are the worst, since they persist longer than the shorter lived weeds. Some annuals are particularly undesirable because they produce an abundance of seed that persists for many years in the soil. The common mustard (*Brassica arvensis* Ktze.) is a weed of this type. Other short-lived weeds may possess especially undesirable characteristics, such as the French weed (*Thlaspi arvense* L.), which usually grows as a winter annual. It produces an abundance of seed, and the plants possess an onionlike flavor which is transmitted to the milk of dairy cows, thus greatly lowering the value of the milk.

The really bad weeds that give the farmer most trouble are the perennials. They are capable of persisting for years even though seed may not be formed. Most of them possess extensive root systems which enable them to store great reserves to tide over unfavorable environmental periods. It is this large stock of reserves that makes it necessary to conduct long periods of cultivation or to use large quantities of chemicals to effect eradication.

Based on their relative harmfulness, weeds have been classed as noxious, semiharmful, and common. Naturally such a classification will vary from state to state, for a weed that is noxious in one area may be of little importance in another where it is unadapted.

The noxious weed plants are those which are especially undesirable because they possess certain attributes that prevent associated crop plants from attaining normal productivity, or for other reasons are extremely harmful. Many types of undesirable trait are exhibited by various weed species. The principle characteristics are persistence and vigor of growth, poisonous properties of the herbage or fruits, or the possession of spines or thorns that may be injurious to animals. Many of the noxious weeds are to be found in the grain fields of the country. Examples of persistent types are the field bindweed (*Convolvulus arvensis* L.) and the Canada thistle (*Cirsium arvense* Scop.) Both of these weeds cause much trouble in both cultivated and uncultivated grain fields in regions where adapted. The cocklebur (*Xanthium canadense* Milli.), a common weed of the grain fields, is poisonous when the plants are small. There are many instances of hogs being poisoned from eating the developing cocklebur. Examples of weeds with injurious spines are the Canada thistle and the sandbur (*Cenchrus pauciflorfux* Benth.). Painful infections, sometimes followed by loss of the animal, may result from the presence of these and similar types of weeds.

The semiharmful weeds are usually so classed to differentiate them

from the especially bad ones. As indicated above, one state may class a weed as noxious, while another state may consider it semiharmful. The semiharmful weeds as a rule are much easier to eliminate than the noxious types. The morning glory (*Convolvulus sepium* L.) is widely distributed in the grain-producing areas. It is not nearly so difficult to control as field bindweed, so it may be classed as semiharmful. The burdock (*Arctium minus* Bernh.), a frequent pest of the fields, is not especially difficult to control but is enough of a menace to warrant classifying it as semiharmful.

The class of common weeds includes the plants which are almost universally present and in general are rather easy to control. For the most part they are annuals. Many of these common weeds are heavy producers of seed, and in the aggregate they cause great losses. Among the common weeds may be listed such plants as the foxtails (*Setaria* spp.), the pigweeds (*Amaranthus* spp.), and lambs'-quarters (*Chenopodium album* L.). Relatively little effort on the part of the farmer will effect the control of these weeds as contrasted with the greater problems in controlling the semiharmful and the noxious varieties. It is probably true that on the average farm the annual weeds occasion more total loss than the more persistent perennial weeds, since they usually are present in much greater abundance and are likely to be given less serious consideration by the grower.

It is suggested that the student become familiar with the weeds that are found in his state and place them in their proper classification based on their undesirable characteristics. Nearly every state has weed publications that apply specifically to its own territory, and these references should prove of great value in the proper evaluation of the weed problems in the growing of grain crops.

WEEDS OF THE GRAIN FIELDS

It is generally recognized that the use of a cultivated crop in the rotation is important in the control of weeds. In the early agricultural development of the country, it was common to grow such crops as wheat almost continuously. Today if the grain crops are not rotated, the farmer practices alternate summer fallow to check weedy growth. To a large extent, especially in the more humid areas where summer fallow is not generally practiced, the grain fields tend to be very weedy. Flax is a very poor weed competitor, and many flax fields are eyesores because of the heavy growth of the foxtails, mustards, pigweeds, and other annuals that should be controlled by a good system of farming.

Oats, barley, wheat, and rye are better weed competitors than is flax

and may possibly be ranked in the above order as to competition with weeds. The more leafy the plant, the greater the tendency for it to shade the ground and thus check annual weed growth. As might be expected, the better a crop serves as a weed competitor, the poorer it is as a companion crop for grasses and legumes. In spite of the greater shading effect of oats, many of the oat fields are so weedy that the presence of weed seeds in the threshed grain becomes an important factor in lowering the market grade. This may be attributed to the type of rotation followed and the lack of weed control in the corn that precedes the oat crop. Faulty seedbed preparation also may be an important factor in the weedy condition of many of the grain fields.

The barley fields tend to be somewhat more free from weeds than the oats in general. This may be due to the fact that barley is usually given the choice of the better fields and frequently is planted in a more carefully prepared seedbed. It is more common to seed barley with a drill on land that has been plowed, whereas oats are often broadcast on disked corn fields.

Wheat and rye are usually seeded on plowed land, and the seedbed is more carefully prepared than for oats. Wheat gets a preferred location on the farm since it is usually grown as a cash crop. Most wheat fields do not become so weedy, although wild oats, mustards, vetches (*Vicia* spp.), and wild buckwheat (*Polygonum convolvulus* L.) may develop in many areas. Rye is often classed as a poor soil crop and is often seeded on the less fertile, more weedy fields; frequently when it is sown on a well-prepared seedbed the weeds are checked.

Buckwheat, because of its rapid growth and broad leaves, is an excellent crop to check many types of weeds. Usually buckwheat fields are relatively free from weeds. The crop has been overrated as a weed-controlling crop as it will not successfully compete with such persistent perennials as field bindweed.

Corn, grain sorghums, and soybeans for grain as commonly grown in cultivated rows offer an opportunity to check many weeds. As usually grown they are not successful in controlling such a weed as field bindweed, since the weed is able to complete its growth after the crop plants are too large for further cultivation. Theoretically, from a weed-control viewpoint, the cultivated crops should reduce the annual weeds to the point where they will be less of a problem during the remainder of the rotation. Actually, this goal is not attained in many cases. The numerous annual weeds often grow in the corn after the last cultivation and produce an abundance of seed to become a problem in succeeding crops. Much may be done to reduce these late weeds by extra tillage at the

start of the crop season to encourage germination and by eliminating the small plants with a harrow or weeder. Some extra hand cultivation after the cultivated crop is laid by will reduce the weed population. Disking the grain stubble or mowing the weeds in the fall preceding plowing for the cultivated crop aids in reducing the weed-seed population giving trouble later in the cultivated crop. It must be remembered that where the weeds have not been controlled for several years considerable time will be required to check them effectively. Only

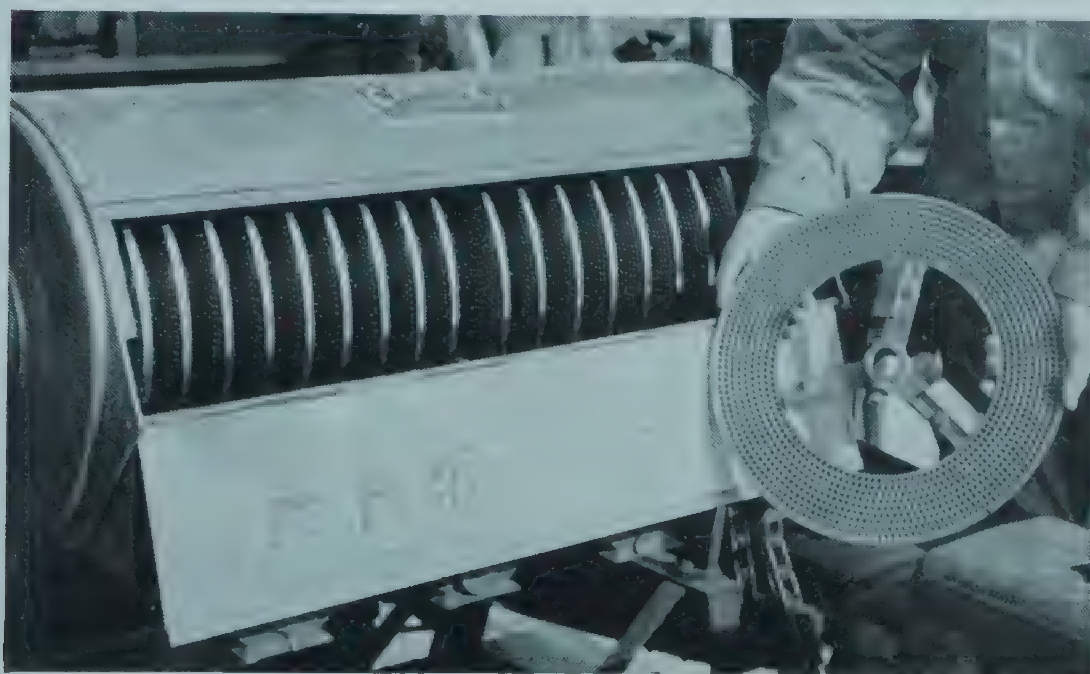


FIG. 29.—The use of good grain-cleaning equipment such as the Carter disk mill is a great aid in weed prevention and control. (*Courtesy of C. E. Skiver, Indiana Agricultural Experiment Station.*)

through persistent effort throughout the entire rotation can one hope to gain control and have fields relatively free of weeds.

CHARACTERISTICS AND FOOD RESERVES OF WEEDS

To understand the principles of weed control one should know something of the physiology of the plant. Many investigations have been made to determine the physiological and anatomical characteristics of weedy plants so that a mode of attack might be planned to strike the weed at its weakest point.

A very important function of the thickened roots and rhizomes of perennial weeds is to store reserve food materials. Some of these reserves may be used during the dormant period of the plant's life, but by far the majority of them remain in reserve until the critical period in the

spring, when the plant must produce considerable new growth of leaves and stems before it can again synthesize all the food materials it needs. Some of the reserve material is used to carry on the normal respiratory processes of the plant as these continue even during the winter, although at a greatly reduced rate. Those plants which are endowed with the capacity of storing great reserves are equipped to survive under unfavorable environmental conditions such as winter or a period of drought. It is only logical to expect that such plants are likely to be extremely persistent and to fall frequently in the category of weeds.

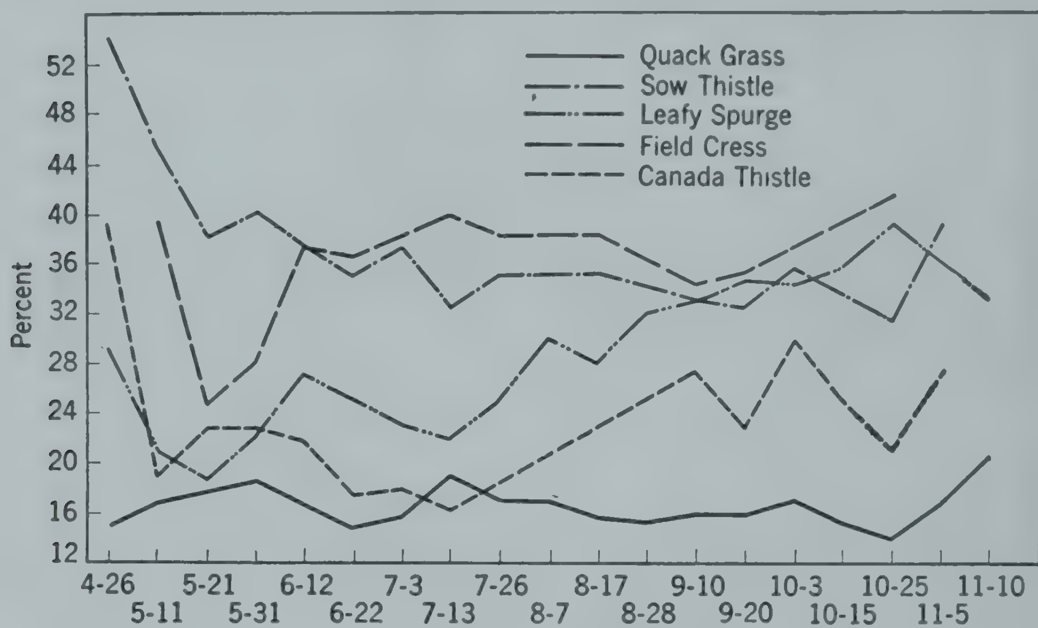


FIG. 30.—Variations in the percentages of total readily available carbohydrates based on dry weights in the underground parts of five perennial weeds. (*Courtesy of A. C. Arny, Minnesota Agricultural Experiment Station.*)

The anatomy of the plant is of importance in a consideration of food reserves. The root characteristics are of especial significance, as they serve as the primary storage organs and thus play an important part in the ability of many species to persist. Bakke[1] found bindweed roots extending into the soil to a depth of 20 ft., providing a tremendous storehouse of reserve food materials for enabling the plant to survive unfavorable environmental periods. This fact helps to explain why it is often necessary to cultivate bindweed-infested land for 2 years in order to exhaust the plant's reserves and cause the death of the weeds.

The character of the reserve materials and the time of storage by the

[1] BAKKE, A. L., Experiments on the Control of European Bindweed (*Convolvulus arvensis* L.), *Iowa Agr. Expt. Sta. Research Bull.* 259, 1939.

plant is of great importance in planning a control program. Arny[1] has made a classic study of the reserve materials of five persistent perennial weeds. Leafy spurge (*Euphorbia esula* L.), Austrian field cress [*Roripa austriaca* (Crantz) Besser], sow thistle (*Sonchus arvensis* L.), and Canada thistle (*Cirsium arvense* Scop.) were lowest in their percentage of total and readily available carbohydrates at the time that the plants began to flower. From this information it is evident that the time of flowering of these weeds is an ideal time to initiate a program of elimination, and this has been found to be true under field conditions. Frequently, a program of fallow may be delayed in its initiation with better results and a decided saving in labor. Cutting the tops of these weeds near the soil surface at the beginning of flowering compels the plant to build a new set of aerial organs, which involves an additional drain on the underground reserves and has the further advantage of preventing seed formation.

As will be indicated later, the programs of chemical treatment for the eradication of perennial weeds are based on a knowledge of the plant reserves and the best opportunity to secure the most effect from a given application.

Such annual broad-leaved weeds as the mustards have been controlled through the use of chemicals based upon a knowledge of the plant's anatomy. The rough surface of the mustard leaf holds and absorbs the spray material, whereas it rolls harmlessly off the glossy leaf of the flax or cereal plant. This has made it possible to use a spray material that is differential in its reaction.

The student of weeds will find it extremely valuable to learn the physical characteristics of both the plants and seeds. Many state and Federal experiment station bulletins contain excellent descriptions and illustrations of the principal weeds of America. A study of the characteristics may well be linked with a study of growth habits and methods of control.

WEED PREVENTION

Effective weed prevention is available to every farmer. It is certain to prove an economy in the end, since comparatively little effort is necessary in most instances. Some of the principles of weed prevention have already been discussed under seed cleaning in Chap. V.

Many of the states have a state seed laboratory where it is possible

[1] ARNY, A. C., Variations in the Organic Reserves in Underground Parts of Five Perennial Weeds from April to November, *Minn. Agr. Expt. Sta. Tech. Bull.* 84, 1932.

for the citizen to send samples for germination and purity tests. If every farmer were to take advantage of these facilities, much of the grain now being planted would be routed to the feed lot. When one considers the total cost of producing a crop, the expense of seed cleaning is a minor item, but considered in the light of the effect on weed control, it is of major importance.

The disking of the stubble field in the fall shortly after grain harvest will destroy many weed plants and prevent the formation of great numbers of weed seeds. If the stubble is not disked, the fall weeds may be mowed before seed formation.

KIND OF SEED__________ VARIETY__________

PURITY %____ GERM. %____ HARD SEEDS %____ DATE GERM.____

WEED SEED %____ NOXIOUS WEED SEED____ NO. PER LB.____

GROWN IN__________ (State) COUNTY__________

FOR HYBRID CORN: ZONE____ MATURITY____ (Days)

Single Cross ( )
Double Cross ( )
Triple Cross ( )

DEALER'S NAME__________

ADDRESS__________, MINN.

FIG. 31.—The type of seed label used in Minnesota.

Extra cultivation in the spring of the year will stimulate weed-seed germination and make it possible to destroy the plants with a minimum of labor.

If a field has become badly infested with weeds it may be advisable to carry on a season of summer fallow to clean up the area. Unless drastic steps are taken on a badly infested field, it is difficult to gain control through ordinary cropping practices.

When buying seed, the purchaser should bear in mind that often the best seed is the cheapest seed regardless of price. Purchases should be made only from reliable firms that have a reputation for dealing fairly. The label on the bag of seed should be studied, as it is the buyer's protection. If the seed is questionable, it is better to return it and secure other seed rather than to risk the planting of undesirable weeds on the farm.

Many of the present weed problems are the result of illegal selling

and the careless buying of seed. Most of the bad weeds in an area are not native but have been introduced in impure seed.

The careless purchase of seed by some farmers is an important means of weed distribution. The purchase of unlabeled seed from a neighbor may result in the acquisition of new weed pests. No seed should be bought on the seller's verbal statement as to its quality. The label is the buyer's protection, and he should insist upon it. Legal and safe seed should carry a complete description similar to the label in Fig. 31.

Fig. 32.—The duckfoot cultivator is a valuable implement in the destruction of many deep-rooted perennial weeds. (*Courtesy of L. M. Stahler, U.S. Department of Agriculture.*)

Such seed may cost more, but experience will prove that it is well worth the added expense.

TILLAGE IN WEED CONTROL

Regardless of the type of rotation followed, usually it is difficult to control weeds without the use of cultivated crops in the rotation. It must be recognized, however, that the proper managment of meadows or pastures may result in weed control without the necessity of a cultivated crop. Since tillage operations are expensive, any increase in their number means an added tax against the crop. The general aspects of tillage have been considered earlier; here the discussion will be related to the elimination of certain types of weeds. While it is impossible to dis-

cuss all weeds in the scope of this text, certain species will be considered, as the principles involved will apply to many others.

Field Bindweed.—This is a serious weed of a great part of the grain-producing section of the country. Where it is adapted, it is extremely difficult to eradicate. In Minnesota[1] it required 2 years of cultivation to secure complete eradication. This involved two plowings at a 5 in. depth and a total of 20 cultivations (10 each year) with a duckfoot cultivator. A tractor was used to draw each of the implements. The estimated cost for the operations over the 2-year period was $12.70 per acre. The total expense would require in addition a cost to be charged against the loss of the use of the land for 2 years.

Time of Beginning Cultivation.—Delaying the initiation of tillage until May or June reduced the number of cultivations necessary to secure bindweed eradication. It was possible, in Minnesota trials, to obtain eradication in one and one-half crop seasons if tillage was initiated before July 1. When the fallow program was started after small-grain harvest, the bindweed had produced seed and it required two full crop seasons to secure eradication. When tillage was started as late as August, it was necessary to cultivate into the third year to secure complete eradication.

Interval between Cultivation.—For many years, it was believed that bindweed tillage should be frequent enough to keep the soil black. However, it was reasoned that after the plants are cut off the new growth must come from the reserves stored in the roots. Experiments made to check this point showed that the interval between cultivations might be extended to advantage. Delaying cultivation until 16 days after the bindweed plants had reemerged reduced the required number of tillage operations as well as the labor costs approximately one-half. All cultivation operations after the initial plowing were made with a power-drawn duckfoot cultivator equipped with wide sweeps that were set to cut to a depth of 5 in.

Perennial Sow Thistle.—This weed is a persistent plant in the areas where adapted. During recent years it has been moving toward the South from its region of greatest importance, northern United States. To secure its elimination the land should be plowed to a depth of 3 to 4 in. during the month of June. Then the soil is disked or cultivated with a duckfoot throughout the entire season, keeping the area black. One

[1] Wilson, H. K., L. M. Stahler, A. C. Arny, R. B. Harvey, A. H. Larson, and R. H. Landon, Battling Weeds on Minnesota Farms, *Minn. Agr. Expt. Sta. Bull.* 363, 1942.

season of tillage should eliminate the thistles. A cultivated crop should follow the fallow, and any weeds that have escaped may be eliminated by machine or hand tillage.

Quack Grass.—This persistent grass plant is a menace in the northern part of the United States, where it frequently becomes troublesome in the grain fields. It may be eliminated by a season of fallow as outlined for sow thistle, although it is advisable to initiate tillage earlier. Where erosion is not a factor, late, shallow fall plowing is desirable. This is followed by a season of tillage to keep the land black. The spring-tooth harrow is valuable to drag out the roots, which may be raked into piles and burned.

Johnson Grass.—This weed is to the South much the same as quack grass is to the North. Helm[1] recommends deep plowing in June, July, or August with the removal and destruction of all roots and tops from each plowed furrow. The land is plowed again in late November and the process repeated the following year until eradication is complete. Lee[2] controlled Johnson grass by plowing winter wheat land as soon as the crop was harvested, with a disk or cultivator being used to keep the land black until fall, when wheat was seeded and the operations repeated a second year.

Canada Thistle.—The infestations of Canada thistle are limited to northern sections. It may be eliminated by one to two seasons of fallow as given for perennial sow thistle. However, it is much more easily controlled through the growing of alfalfa. Two to three years of alfalfa with at least three harvests per season will destroy most stands of Canada thistle, as the weed cannot recover after cutting as rapidly as alfalfa.

CROPS IN WEED CONTROL

The ideal method of controlling weeds is to grow a desired crop that is able to compete with the weedy plant and bring about its elimination. Unfortunately, not many crops are capable of giving such results. There are types of combinations in which tillage and crops are combined to reduce the costs and effectively control the weeds.

Many farmers have referred to certain crop plants as *smother crops*. Buckwheat is an example of such a crop. This designation is misleading, since no crop really smothers another. What actually happens

[1] HELM, C. A., Johnson Grass, *Mo. Agr. Expt. Sta. Ext. Leaflet* 45, 1936.

[2] LEE, O. C., Johnson Grass and Its Control in Indiana, *Purdue Agr. Expt. Sta. Ext. Leaflet* 201, 1936.

is that the so-called smother crop effectively competes with the weeds; it should more properly be referred to as a *competitive crop.*

Usually it requires more time to eliminate weeds through competitive crops than through tillage or chemicals. However, there is the big advantage of providing for a regular income even though it may be reduced. The use of competitive crops may be illustrated by their effectiveness in checking field bindweed. For convenience of description, they may be classed as fall and summer competitive crops, based upon the time of planting.

Fall Competitive Crops.—In much of the bindweed area, rye or winter wheat is grown. A full season of tillage is carried out until the latest desirable date for seeding wheat or rye, when the crop is seeded and left on the land until harvested. Just as soon as possible after harvest, the land is plowed and duckfooted at 2-week intervals until fall, when the winter grain is again seeded. Under South Dakota and Minnesota conditions it has been possible to eliminate field bindweed within 2 or 3 years by this method. At the same time, crops were produced to cover the cost of the tillage, which was greatly lessened by the combination plan. In many cases, however, deleterious soil effects often follow this plan with greatly reduced yields of grain. The method is not favored by many farmers for this reason.

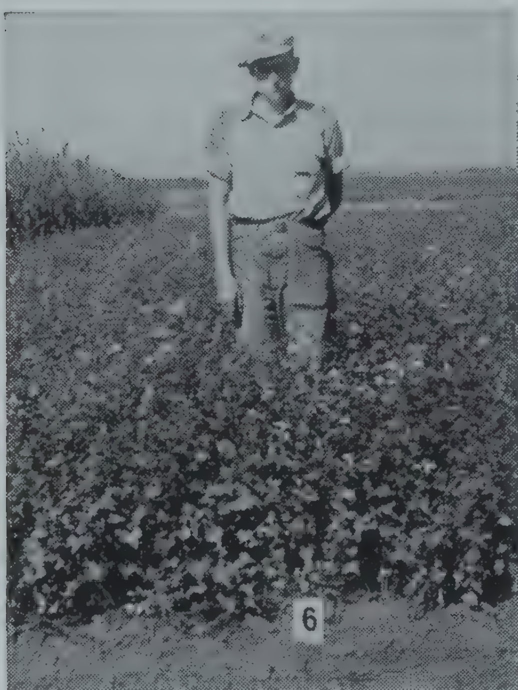


FIG. 33.—Soybeans planted after early summer tillage are valuable in the control of field bindweed. (*Courtesy of L. M. Stahler, U.S. Department of Agriculture.*)

Summer Competitive Crops.—The land is plowed in June and cultivated at intervals of 2 weeks until about July 1 when soybeans, Sudan grass, millet, or sorghum is planted at a heavy rate. It is advisable to use a cultipacker to firm the seedbed and thus favor more rapid germination of the crop seed. The crops will grow rapidly and should compete with the bindweed. The hay crop is harvested just before frost, and the operation is repeated for a second or third year. If this treatment is followed by a cultivated crop, one can detect any plants that may have persisted and treat them with an application of sodium chlorate or remove them by hand tillage.

CHEMICALS IN WEED CONTROL

To many, the use of chemicals for weed control is alluring. They like to think of the chemical herbicide as a selective agent, capable of destroying the unwanted weed and leaving the crop unharmed. Generally such a chemical is not available, and the person who carelessly permits bad weeds to gain a foothold must expect that only through labor and expense can he hope to get rid of the undesirable plants.

Types of Chemicals.—Many chemicals have been tested for their value as herbicides, but only a few have a place in agriculture. Sulfuric acid was one of the first chemicals used in weed control and even today has a place in the control of certain types of annual weeds found in grain fields.

Ordinary salt, or sodium chloride, is an effective weed killer, but its cost is too great to warrant use. Further, if applied at a heavy rate it tends to leave the soil more or less permanently sterile.

Carbon bisulfide, a very explosive compound, has been used with some success, but its cost is great and its highly explosive nature has prevented its extensive use. In addition to the cost of the chemical must be added an enormous labor cost since the liquid is placed in holes punched into the soil at close intervals.

The arsenical compounds have proved effective in the control of many weeds but are not usually recommended in the humid areas because of their very poisonous nature. The hazard to livestock may persist for a long period, and this has operated to make these chemicals unpopular.

Borax has shown some promise as a herbicide. In Minnesota trials it has proved effective in killing leafy spurge and field bindweed. It has the advantage of being nonexplosive and is easy to handle. Although it is poisonous there is no danger to livestock since they will not eat it because of its unpleasant taste.

Sodium chlorate, a chemical resembling common salt in appearance, is the most widely used herbicide. In fact, livestock will eat chlorate if given an opportunity. It is poisonous to livestock if eaten in any quantity and is highly inflammable, and when mixed with organic matter it becomes a dangerous explosive. For these reasons chlorate must be used with great care if one is to avoid an accident.

Sodium dinitro-ortho-cresylate[1] is a compound that has been used effectively to destroy the broad-leaved weeds such as the mustards without appreciable injury to the growing crop of grain. A commercial form of this chemical is sold under the name of Sinox.

[1] Harris, L. E., and G. R. Hyslop, Selective Sprays for Weed Control, *Ore. Agr. Expt. Sta. Bull.* 403, 1942.

When to Use Chemicals.—One cannot set up a definite rule for the use of most chemicals. In general, the cost is so great that their use

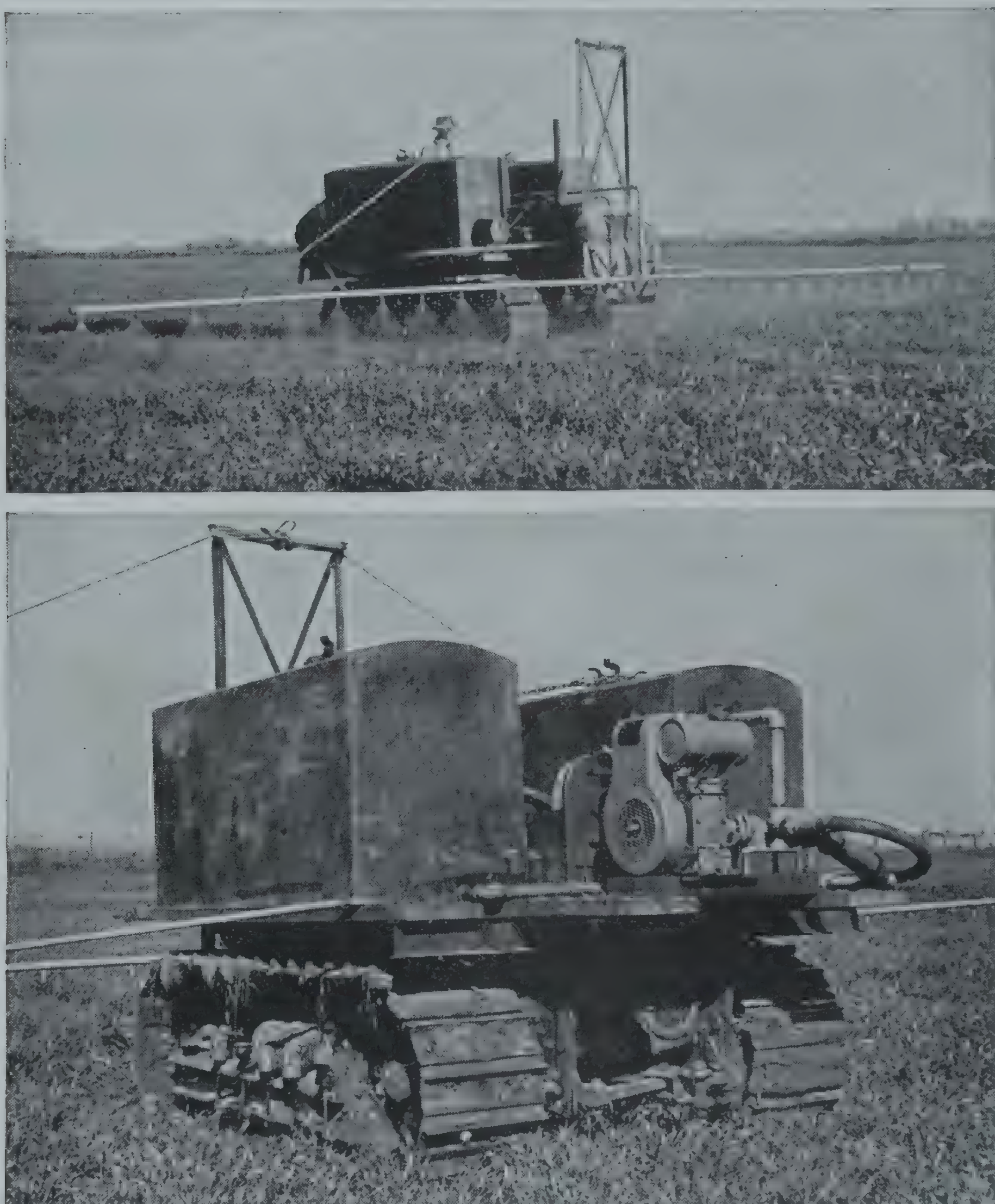


FIG. 34.—Two views of a field sprayer used in applying Sinox. Top, front view showing boom in operation. Bottom, rear view showing pump assembly. (*After Robbins, Crafts, and Raynor.*)

usually is not justified on large areas. It would appear that where the total infestation is more than 2 or 3 acres in area it may be advisable to use other methods of control. If a small area is infested with a noxious

weed, one can well afford to spend a considerable amount for chemicals to make certain that the weed is checked before it has an opportunity to infest the entire farm.

A chemical such as Sinox may be used to advantage where there is a heavy infestation of mustard in the grain field. Since the chemical is

FIG. 35.—The Gandy spreader for applying dry chemicals. This machine may be used to spread herbicides, fertilizers, or fine seeds. (*After Robbins, Crafts, and Raynor.*)

applied at rates that require small expenditure for materials, the cost is not nearly so great as for such a herbicide as sodium chlorate. The use of Sinox has increased greatly in the grain sections during recent years.

The Use of Sodium Chlorate.—Sodium chlorate has proved effective in eliminating a great variety of weeds. Although there is some agreement among workers as to methods of use, variations in results occur, as would be expected.

Time of Application.—Sodium chlorate is usually most effective if

applied in the late summer or fall. Under most conditions early summer applications may prove very ineffective, and failures have resulted when the treatment was made before July 1. It appears that the plants are more readily injured later in the season, and at that time the chemical is less affected by environmental conditions.

Method of Application.—Both the spray and the dry method of application are effective. The use of the spray requires the purchase of costly spray equipment, while a relatively low-priced spreader effectively spreads the dry salt. It is certain that there is much less fire hazard from the use of dry chlorate than when it is applied in solution. Several accidents have occurred from the use of the spray when previously wet clothing was ignited upon drying.

TABLE 27.—SURVIVAL OF FIELD BINDWEED TREATED WITH SODIUM CHLORATE APPLIED AT INDICATED RATES PER ACRE, LAMBERTON, MINN.*
(1936–1939 average)

Rate per acre, lb.	Average number of plants in a square yard surviving on July 15 of following year	
	Applied as dry salt	Applied as spray
200	4.4	4.6
300	2.4	3.3
400	1.2	1.4
500	0.1	0.4
600	0.3	Trace
700	0.1	0.2
800	0.0	0.0
Untreated check	17.0	17.0

* Adapted from H. K. Wilson *et al.*, Battling Weeds on Minnesota Farms, *Minn. Agr. Expt. Sta. Bull.* 363, 1942.

Since it is generally agreed that the chlorate kills the plant by entering through the root system, it seems desirable to get it on the soil surface, and this is accomplished effectively by the dry method of application. When it is sprayed on the foliage, a certain amount of the chlorate is retained by the plants and does not enter the soil at once. Also, the treated foliage is very inflammable, and a stray fire will destroy all chlorate and thus reduce its total effect on the weeds.

Where the ground is rough or stony or otherwise inaccessible it may be desirable to use the spray, since it is possible to cover such terrain more easily by this means than with a spreader.

On a small area, as in patches on a field, the salt may be applied by hand. Before this is done, the operator should practice to make certain that he is not applying a great excess. The tendency of most workers who apply the chemicals by hand is to put on much more chlorate than is necessary.

Rate of Application.—The rate of application will vary with the weed, the soil, and the rainfall. Generally, more chemical is required to kill a weed in the region where it is best adapted than in a section

FIG. 36.—The effect of Sinox on mustard in flax. To left, sprayed; to right, unsprayed. (*Courtesy of W. W. Brookins, Central Fibre Corporation.*)

less suited to its best growth. In Minnesota, approximately 3 to 4 lb. of chlorate per square rod usually kills field bindweed. In Kansas somewhat heavier applications are required, and it is common to repeat the treatment with lessened amounts the following year. It is evident that the cost of chlorate is great, often amounting to as much as $75 per acre, a tax that is prohibitive on most farms except on small areas.

The Use of Sinox.—This chemical has gained greatly in popularity during recent years. The Sinox chemical is diluted in water to which ammonium sulfate has been added and sprayed at low pressure when the broad-leaved weeds such as the mustard are in the rosette stage. The action is such that the weed leaf absorbs the poison and dies as a result, while the leaves of the cereals and flax shed the chemical with little or no injury. The weedy grasses such as the foxtails are not affected by Sinox.

A large sprayer with a long boom is necessary for the economical application of Sinox. Specially built units are commonly used, since the

ordinary spray rig is not suited to give the proper volume of spray at the desired pressure. Considerable water is required, as 80 gal. of the mixture is applied to flax and 100 gal. to the small grains.

Other Chemicals.—It is impractical here to discuss all phases of chemicals in weed control. The interested student will find the book "Weed Control," by Robbins *et al.*,[1] to be a valuable reference to this and other phases of the weed problems.

HORMONE WEED ERADICANTS

In 1944, Hamner and Tukey[2] reported promising results from the use of certain hormones in the control of weeds. This work led to the initiation of numerous investigations in the field of hormones and noxious plant control. Results have been promising, but much further study is needed to determine the conditions under which eradicants of this type will prove effective.

Hildebrand[3] has given a detailed discussion of these materials as well as other of the more promising herbicides that have been developed in recent years.

LIVESTOCK IN WEED CONTROL

The use of livestock to control weeds offers an economical and effective plan under many conditions. The sheep and the goat are probably the best animals to eat plants that are avoided by most classes of livestock, and they tend to graze closely and thus prevent plant recovery.

At the Lamberton, Minnesota, Weed Station a period of cultivation followed by rye or winter wheat grazed heavily in the spring until the crop was consumed eliminated field bindweed within two to three seasons. The rye or wheat may be supplemented by immediately plowing the grazed land in the early summer, seeding Sudan grass, and continuing the grazing until time to plant the winter grain in the fall. This program provided an abundance of feed and was very effective in checking the bindweed.

In a bluegrass pasture, the stand of field bindweed was greatly reduced where overgrazing was avoided and the pasture was given a liberal coating of barnyard manure to stimulate the grass.

[1] ROBBINS, W. W., A. S. CRAFTS, and R. N. RAYNOR, "Weed Control," McGraw-Hill Book Company, Inc., New York, 1942.

[2] HAMNER, CHARLES L., and H. B. TUKEY, The Herbicidal Action of 2,4 Dichlorophenoxyacetic and 2,4,5 Trichlorophenoxyacetic Acid on Bindweed, *Science*, 100, **100**: 154–155, 1944.

[3] HILDEBRAND, E. M., War on Weeds, *Science*, **103**: 465–468, 1946.

Helgeson and Thompson[1] were successful in eliminating large areas of leafy spurge through grazing with sheep. Similar results have been obtained by the Minnesota Agricultural Experiment Station.

In work at the Lamberton Weed Station, growing chickens confined to bindweed-infested land successfully eliminated the weeds within one season. This offers a means of cleaning up small areas of infestation.

FIG. 37.—Sheep pastured on rye to eradicate field bindweed. (*Courtesy L. M. Stahler, U.S. Department of Agriculture.*)

WEED LAWS

Nearly every state has a set of weed laws designed to protect the farmer against poor seed, but good laws protect both the buyer and the seller. The honest dealer looks upon proper seed laws as an asset to his business.

The weed and seed laws are of value only as they are enforced. Too many farmers are unfamiliar with the provisions of their state laws and so are unable to gain the most from the protection they offer. While most states have weed and seed laws that prevent dealers from the sale of undesirable seeds, there is little checking of the farmer who sells weedy seed to his neighbor. In its ultimate effect the result is the same whether one secures bad weeds from a seed company or from a neighbor. Often the sale of poor seed by the neighbor is the result of ignorance of the law and the presence of the weed seeds. Most states are able to provide a check on the quality of seed, and the farmer should get in touch with his county agent, agricultural teacher, state seed laboratory, or state agri-

[1] HELGESON, E. A., and E. J. THOMPSON, Grazing in Relation to the Control of Leafy Spurge, *Science*, 88: 57, 1938.

cultural experiment station. In the same manner the buyer should avail himself of these same services.

The various state crop-improvement associations have been of great value to the farmers of their respective states since their efforts have led to the production and sale of superior quality seed and a better control of seed distribution. Usually these associations work closely with the state agricultural experiment stations in promoting the use of clean seed and the control of the unscrupulous dealer who sells unadapted, undesirable seeds to the farmers of the state. If the farmers of the state can be shown the value of good seed and are willing to insist upon securing it, great progress will be made toward solving the state's weed problems.

Review Questions

1. In your own words define the term *weed*.
2. List the types of damage caused by weeds that you have observed.
3. What characteristics make some weeds worse than others?
4. Why do weeds tend to become worse where tilled crops are not grown?
5. What weeds are usually found in the grain fields in your region?
6. List the worst weeds of your section.
7. Set down the reasons why each weed listed in answer to Question 6 is so catalogued.
8. How are food reserves related to a weed being very persistent?
9. Explain why weed prevention is usually the cheapest way to combat weedy plants.
10. How does a state seed laboratory aid in weed control?
11. How may crops be used in weed control?
12. What part do chemicals play in weed control?
13. Under what conditions would you use chemicals to control weeds?
14. What are the limitations of chemicals in a program of weed control?
15. How can one best control annual weeds?
16. How may livestock aid in the control of weeds?
17. What is the significance of hormones in weed control?
18. How can a crop-improvement association benefit from close cooperation with the state seed laboratory?
19. What is a selective spray?
20. How long can weed seeds survive in the soil?
21. Which farm animals do the best job of destroying weed seeds that they eat?

References

Ball, W. S., A. S. Crafts, B. A. Madson, and W. W. Robbins: Weed Control, *Calif. Agr. Expt. Circ.* 97, revised by R. N. Raynor, 1940.

Brookins, W. W.: "Weeds in Flax," published by Central Fibre Corp., Pisgah Forest, N. C., 1944.

Brown, E. O., and R. H. Porter: The Viability and Germination of Seeds of *Convolvulus arvensis* L. and Other Perennial Weeds, *Iowa Agr. Expt. Sta. Research Bull.* 294, 1942.

Darlington, H. T., E. A. Bessey, and C. R. Megee: Some Important Michigan Weeds, *Mich. Agr. Expt. Sta. Special Bull.* 304, 1940.

Drew, W. B., and C. A. Helm: Representative Missouri Weeds and Their Control, *Mo. Agr. Expt. Sta. Bull.* 433, 1941.

Harvey, R. B., A. H. Larson, R. H. Landon, and L. C. Erickson: Pesky Plants, *Minn. Agr. Expt. Sta. Bull.* 381, 1944.

Litzenberger, S. C., A. H. Post, and H. E. Morris: Important Perennial Weeds in Montana, Their Identification and Control, *Mont. Agr. Expt. Sta. Bull.* 426, 1945.

———, ———, and G. H. Bingham: Controlling Broad-leaved Annual and Biennial Weeds with Sinox, *Mont. Agr. Expt. Sta. Bull.* 430, 1945.

Seely, C. I., K. H. Klages, and E. G. Schafer: Bindweed Control, *Wash. Agr. Expt. Sta. Popular Bull.* 176, 1944.

Shedd, C. K., E. V. Collins, and J. B. Davidson: Weed Control in Growing Corn, *Iowa Agr. Expt. Sta. Bull.* p. 44, 1942.

Timmons, F. L.: Results of Bindweed Control Experiments at the Fort Hays Branch Station, Hays, Kansas, 1935–1940, *Kans. Agr. Expt. Sta. Bull.* 296, 1941.

Wilson, H. K.: Control of Noxious Plants, *Botan. Rev.*, **10**: 279–326, 1944.

———, L. M. Stahler, A. C. Arny, R. B. Harvey, A. H. Larson, and R. H. Landon: Battling Weeds on Minnesota Farms, *Minn. Agr. Expt. Sta. Bull.* 363, 1942.

CHAPTER VII

DISEASES OF GRAIN CROPS

A study of the diseases of grain crops is a subject in itself, and for a full understanding special training in plant pathology courses is desirable. It is possible, however, to present certain principles as they pertain to crop production so that the student may gain a better understanding of diseases as related to the various crops. The discussion will be confined to the crops that are grown primarily for grain and to those diseases which are of greatest importance.

IMPORTANCE OF DISEASES

As indicated in the previous chapter, the United States Chamber of Commerce has estimated the annual loss from plant diseases to be more than one billion dollars, truly a tremendous tax on American farmers. In years when diseases occur in epidemic proportions the losses may be even greater. It was estimated by Dr. E. C. Stakman[1] that, in 1916, rust alone caused a loss in the United States of more than 180,000,000 bu. of wheat and for the same year in Canada losses of about 100,000,000 bu. Similar losses have been experienced in the other grain crops in years when diseases become epidemic. Many farmers have experienced such severe losses from rust that their crop was almost entirely destroyed.

Sometimes the smuts assume epidemic proportions, but nearly every year they occasion losses that may not be noted by the farmer. Certain diseases of corn, wheat, and barley may effect considerable loss, especially in the seedling stage of the plant. Most farmers do not appreciate the extent of these losses, but it is safe to assume that on an average they represent an appreciable economic loss every year.

GENERAL PRINCIPLES OF DISEASE CONTROL

Before discussing the diseases of specific crops it appears desirable to consider certain principles more or less applicable to the plant diseases as a group.

As is the case with human beings, certain plant diseases may be the result of improper nutritional conditions or other environmental factors that may render the plant more susceptible to attack. Beyond a doubt,

[1] Heald, F. D., "Manual of Plant Diseases," McGraw-Hill Book Company, Inc., New York, 1926.

high humidity, heavy dews, and the presence of an abundance of spores may lead to a serious epidemic of rust. Even varieties that are very susceptible to diseases may escape injury either because inoculum was not present or because conditions were especially favorable for the normal development of the plant.

Several principles must be considered in a discussion of grain-crop diseases. These include (1) disease prevention, (2) seed treatment, and (3) breeding for disease resistance.

Disease Prevention.—In human physiology, prevention is given great emphasis and has proved very effective in avoiding epidemics and stopping diseases soon after they appear. In every large city many of the contagious diseases are present in isolated spots. Through quarantine and other methods they are usually checked so that an epidemic does not develop. With plant diseases, it is possible to do much to prevent diseases through practices available to the farmer. Such a simple practice as doing a good job of plowing under the cornstalks may prevent an epidemic of scab on the barley crop that follows.

The proper use of the fanning mill may remove numerous smut balls which by their presence make possible the infestation of clean seed and thus perpetuate the organism the following year.

The cutting of weedy grasses near the field may aid in the control of such diseases as ergot. The ergot bodies often develop in the flowers of grasses, such as quack grass, growing on the edge of a grain field. These organisms fall to the ground and provide inoculum for the rye crop that may be seeded the following year.

The common barberry is an alternate host of black stem rust, and its relationship to black stem rust is well known.[1] The rust starts its life cycle on the barberry bush in the spring, and yellowish or orange-colored rust spots form on the leaves, young twigs, and berries. On the underside of the leaves are many small cups (cluster cups) that contain thousands of spores. These spores (aeciospores) are carried by the wind and may fall on grain or grass plants to produce an infection that develops red pustules on the leaves and stems. This is the stage that farmers refer to as *red rust* because of its color. Being a parasite, the rust organism draws nourishment from the growing plant, and in severe cases infections may be so numerous that the plant is severely injured or killed.

The red rust spores (urediospores) are small and light and are readily carried by the wind to other grain or grass plants, where they produce

[1] Stakman, E. C., The Black Stem Rust and the Barberry, Separate from the *U.S. Dept. Agr., Yearbook of Agriculture* 796, 1918.

new infections. This explains how an infection may start in one spot in a field and rapidly progress until the entire crop is infected.

Late in the season when conditions are no longer favorable for the rapid increase of the red spore stage, it is replaced by the black spore stage. The organism that infects the leaf or stem develops a different type of spore which is black in color. At this stage the farmer normally refers to it as *black rust.* These black spores (teliospores) are not blown by the wind and do not germinate immediately. They remain on the straw and stubble of the grain over winter and constitute a resting stage of the rust fungus. The teliospores cannot infect grain plants but grow only on the barberry. In the spring, the black spores germinate and produce very small colorless spores, known as *sporidia,* which may be carried great distances to infect the barberry. Within a week to 10 days after the spore falls on a barberry leaf, it produces infection and the cycle is completed.

Rust that overwinters in the uredial stage, as in the South where the winters are mild, may move great distances, the urediospores being carried by the winds. It is common to observe the movement of an epidemic from the South to the North as the inoculum spreads from region to region.

The barberry is especially undesirable since it has been shown that new strains and types of rust are developed on its leaves by hybridization. These new varieties are commonly referred to as *races.* A given variety of grain crop may be resistant to several of these races and yet be very susceptible to others. As long as the barberry continues to grow it is a constant threat to existing varieties possessing black stem rust resistance. Also the presence of barberry bushes has been shown to result in more severe epidemics and greater injury to grain fields near by.

Considerable effort has been expended to eliminate the common barberry. This type of prevention is of great importance in disease control.

Seed Treatments.—One of the oldest methods of controlling plant diseases is to treat the seed so as to destroy the disease organism and prevent it from development.

Seed treatments fall into two general categories: (1) chemicals applied to the surface of the seed to destroy the disease organism, and (2) the application of heat to destroy organisms that are within the seed and thus protected from injury when chemicals are applied.

Chemical Disinfectants.—These include the various treatments that are applied to the seed to destroy pathogens carried on its surface.

Brentzel[1] has given the requirements of a seed disinfectant as follows:

1. It must avoid injury to the seed.
2. It must destroy seed-borne organisms.
3. Disinfectant should be useful on several kinds of seeds.
4. Treatment should destroy several kinds of disease germs.
5. It is preferable to have a treatment that does not render the seed poisonous to livestock which may be fed unsown seed.
6. Treatment should not be injurious to the operator.
7. Disinfectant should not injure treated seed held in storage.
8. It is desirable that treatment should check soil-borne disease organisms.
9. Treatment should not prevent free movement of seed through the drill.
10. The cost should be low.

Kiesselbach and Lyness[2] compared various types of seed treatments for the control of smut on winter wheat.

TABLE 28.—COMPARATIVE TEST OF MISCELLANEOUS SEED TREATMENTS WHEN APPLIED TO HEAVILY SMUTTED SEED WHEAT, LINCOLN, NEB., 1938

Treatment Applied to the Seed	Bunted Heads, Per Cent
No treatment	46.6
Formaldehyde, soaking method (1 pt. to 40 gal.)	0.4
Copper carbonate (20%) 2½ oz. per bu.	1.5
New Improved Ceresan (5% ethyl mercuric phosphate) ½ oz. per bu.	0.4
Cuprocide (red copper oxide) 2½ oz. per bu.	0.3
Monohydrated copper sulphate (35% metallic copper) 2½ oz. per bu.	2.5
Barbak C. (8% mercuric phenyl cyanamid and 2½% cadmium oxide) 2½ oz. per bu.	8.8
Leafox 200 (zinc oxide 98.5%) 2½ oz. per bu.	22.7
Leafox 200A (zinc oxide, experimental) 2½ oz. per bu.	19.3

The authors state that, of the various fungicides tested for a period of 3 to 8 years, copper carbonate and New Improved Ceresan have proved most practical and highly effective in smut control without

[1] BRENTZEL, W. E., Studies on Seed Treatments for Cereal Crops, *N. D. Agr. Expt. Sta. Bull.* 331, 1944.

[2] KIESSELBACH, T. A., and W. E. LYNESS, The Effects of Stinking Smut (Bunt) and Seed Treatment upon the Yield of Winter Wheat, *Neb. Agr. Expt. Sta. Research Bull.* 110, 1939.

injury to the seed. They recommend 2½ to 3 oz. of 20 per cent copper carbonate to 2 oz. of 50 per cent copper carbonate or ½ oz. of New Improved Ceresan per bushel of grain.

Seed treatment is necessary if one is to grow susceptible varieties successfully, especially in the Pacific Northwest or Coast areas where smut is much more prevalent. Johnson[1] and his associates recommend three general types of seed treatment for the control of bunt:

Apply New Improved Ceresan at the rate of one-half ounce per bushel in a mixing machine or as recommended in directions of the container. The treated grain should be kept uncovered in a bin, pile, wagon box, or sacks for at least 24 hours before seeding. Treated grain may then be seeded at once or stored. Ordinarily it should not be stored more than 4 weeks before seeding time, because of uncertainty as to the effect on seed germination after this period. Do not apply more than one-half ounce of this disinfectant per bushel as an excess may injure germination.

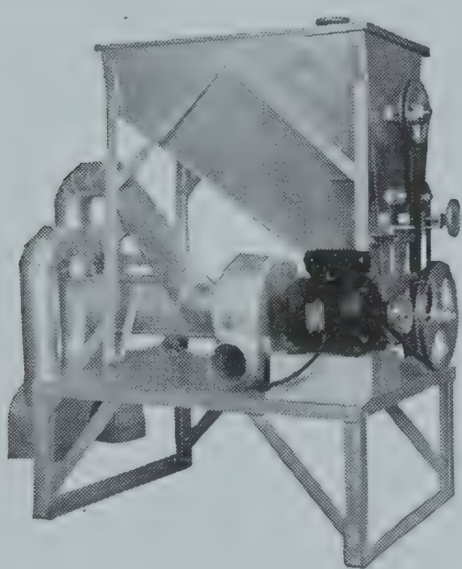


FIG. 38.—A commercial seed-treating machine. (*Courtesy of Ben Gustafson Seed Grain Machinery Company.*)

Copper carbonate dust has long been used for the control of covered smut. It is advisable to use full-strength material (about 50 per cent copper) as made expressly for seed treatment. This dust is applied to the grain at the rate of 2 to 2½ oz. per bushel. The seed and the dust are mixed thoroughly. Treated seed may be stored indefinitely without injury to germination. Since it is poisonous, care must be taken to avoid the accidental feeding of treated grain. In damp weather treated seed may become caked, and it is desirable to rock the wheels of the grain drill backward and forward before starting to make certain that the grain has not locked any part of the drill. It is well to clean the drill thoroughly after seeding to avoid corrosion by the copper dust.

The copper sulfate treatment requires the use of full-strength basic copper sulfate dust (about 50 per cent copper) as made expressly for seed treatment. This dust is applied to the seed at the rate of 2 oz. per bushel in the same manner as outlined for the copper carbonate dust, and the same precautions should be followed in its use.

[1] JOHNSON, A. C., R. W. LEUKEL, and R. J. HASKELL, Treat Seed Grain, *U.S. Dept. Agr. Misc. Pub.* 219, 1944.

In general, several types of organic mercury-bearing compounds have proved acceptable. Several brands are available on the market and are used by many growers to treat their cereal seeds. There is considerable evidence to show that some of these treatments prove beneficial to low-quality seed, resulting in better germination and more rapid seedling growth.

Moore[1] has developed an excellent device for use in seed treatment. Known as the Minnesota Seed Grain Treater, it may be constructed from materials that in normal times cost less than $5. Many growers have used this machine and find it well suited to their requirements. For larger scale operations where considerable seed is treated, it is advisable to employ a specialized machine capable of treating a large quantity of seed within a short period of time.

Heat Treatment.—Heat is used to raise the temperature to the point where the organism is destroyed but not high enough to kill the seed. As would be expected, the operation is a difficult one that should not be practiced except by experienced individuals.

Seed treatment has been used to control loose smut, but the methods differ widely from those used on covered smut. Since this disease is carried within the seed, any external application of chemicals is ineffective. The use of high temperatures makes it possible to destroy the disease organism without killing the seed.

The general plan of the modified hot-water treatment is as follows: (1) Place the wheat in bags and immerse in water at 70°F. for 4 to 6 hr.; (2) remove bags, drain quickly and immerse for 10 min. in water at 129°F.; (3) remove the bags, drain, and immerse in cold water to reduce the temperature; (4) spread the seed in a thin layer to dry. The use of a fan or a blast of warm air will speed the drying process. As soon as the grain is dry, it should be tested for germination as the treatment may reduce it greatly. If the germination percentage is lowered, the rate of seeding may be increased accordingly.

The hot-water-treatment method is difficult to apply and should not be done by amateurs. Few farmers possess the equipment necessary to do a successful job. In many areas, community treating is done at the local creamery or similar place providing an abundance of hot water. It is essential that temperatures be regulated and all details followed with care.

It is impractical under most conditions to treat the entire lot of seed to be used on the farm. A more practical plan is to treat enough seed

[1] Moore, M. B., The Minnesota Seed Grain Treater, *Minn. Agr. Ext. Folder* 118, 1943.

to sow an isolated seed plot to provide for the next year's seeding. The size of the plot will be dependent upon the quantity of seed required, based upon yields that may normally be expected.

Breeding for Disease Resistance.—The plant breeder is constantly striving to control plant diseases through methods of breeding. In the early days, such improvement took the form of simple selection, locating resistant plants and then increasing them for the use of the farmer. Much progress has been made in this direction.

Today the modern plant breeder works hand in hand with the plant pathologist to breed for disease resistance. Search is made for superior germ plasm to be used in the development of superior varieties not only possessing superior agronomic qualities but also insofar as possible bred for their resistance to diseases. In some cases, much progress has been made; in others, little or no progress can be shown. Since the disease organisms are ever subject to change, the plant breeder is not surprised when his newly developed disease-resistant variety later is attacked by disease and must be replaced. There are numerous cases of this type. Ceres and Thatcher spring wheat varieties performed well for many years, then they were injured more and more by the rusts until they were replaced by later improved varieties. It is to be expected that such changes may occur. This should not deter the breeder but rather stimulate him to greater effort, as the problem seems to be a constant challenge.

Breeding for disease resistance is not the ultimate answer to all disease problems. It would be ideal if this were possible, but the student must be realistic. Each of the phases of control has its place, and each should supplement the other whenever necessary.

DISEASES OF SPECIFIC CROPS

While the principles discussed above apply in general to most of the grain crops, it is desirable that each of the major crops be considered separately in relation to its most serious diseases. Naturally, symptoms and controls tend to overlap to some extent.

Wheat

Wheat is an important cash crop in many parts of the country, and an epidemic of a disease such as stem rust has a pronounced effect on market prices. As wheat prices often tend to set the pace for other grain prices, the entire market grain structure may be affected by a reduction in yield.

Black Stem Rust.—This disease, caused by *Puccinia graminis tritici*

Eriks. and Henn., is found wherever wheat is grown. For many years it has been the scourge of wheat fields, frequently being so severe as to make production unprofitable.

Many physiologic forms or races of this rust are known to exist. While a variety of wheat may be resistant to one race, it may prove to be very susceptible to another. It is desirable that a new and improved variety be resistant to all the races existing in a given region if severe epidemics are to be avoided.

High air temperatures together with an abundance of moisture favor the development of black stem rust. A period of warm days with heavy dews to wet the grain vegetation thoroughly is ideal for infection by the rust organism.

The growing of susceptible crop varieties favors the spread of the disease. As new races of rust may develop, it is possible for resistant varieties to prove susceptible to a newly formed race. The growing of susceptible varieties in an area aids in the building up of a mass of inoculum that favors a more rapid spread of the rust epidemic.

Certain cultural practices affect the development of black stem rust. Too thick seeding of the crop may delay maturity and thus increase the danger of infection to susceptible varieties. Late planting of the crop may increase the dangers from rust, since maturity may be delayed and thus the plant may be subjected to a more unfavorable environment and be more susceptible to infection. Also, there may be much more inoculum present later in the season. A heavy growth of weedy plants in the grain fields helps to hold the water from the dew and rains and favors conditions favorable to the development of rust.

Controlling Black Stem Rust.—Naturally, the ideal means of controlling any disease is to eliminate sources of infection. Much work has been done to eliminate the barberry in many areas. However, inoculum moves from the South to the North, and it has been impossible to destroy the pathogens.

The logical alternative to destroying the organism would be to breed varieties that are immune or resistant to the disease. If this were done, then the disease might be of little importance. Much good work has been done in stem rust control, as the plant breeder in cooperation with the pathologist has developed many varieties that possess marked resistance to black stem rust. The success of the programs is illustrated by the fact that most of the acreage in the hard red spring wheat area is now planted to resistant varieties.

Certain other measures have been used with some degree of success to control stem rust. The use of a sulfur dust applied to the infected

plants reduced the infection but has not proved economical. The application of phosphatic fertilizers to hasten maturity has been of some value. Early seeding may permit a susceptible variety to escape serious damage as the plant may be mature before the development of a severe epidemic. In summation, it appears probable that the use of available resistant varieties offers the greatest promise of a successful and economical method of control.

Leaf Rust of Wheat.—*Puccinia triticina* Eriks. is a disease that is common in the wheat-growing sections, but probably its relative impor-

FIG. 39.—Leaves of wheat showing uredinia of *Puccinia triticina* and the hypersensitive areas caused by this rust. (*After Heald.*)

tance has been overlooked by many because of the much greater seriousness of black stem rust. Now that black stem rust is being controlled by the growing of resistant varieties, there is a greater appreciation of the importance of leaf rust as a limiting factor in wheat production.

Life Cycle of Leaf Rust.—The organism overwinters in the uredial stage on either winter grains or grasses, forming urediospores in the spring which infect the growing plants. The disease is known as *leaf rust* because the infection occurs on the leaf and leaf sheaths but not on the stem. The light-yellow pustules are more or less round and do not rupture the leaf surface as does stem rust. A fall favorable to the devel-

opment of the organisms usually results in an epidemic the following year.

Covered Smut of Wheat.—This disease, commonly known as *bunt*, has been responsible for much damage. Some years ago it was not uncommon in the Pacific Northwest for a threshing machine to burn as

FIG. 40.—Smutted and normal heads of Jones Winter Fife and Hybrid 128. (*After Heald.*)

a result of an explosion induced by the great mass of smut spores that accumulated in the machine. There are two species of wheat smut, *Tilletia levis* Kühn and *T. tritici* (Bjerk.) Wint. *T. levis* is the most common in the Central and Eastern states, while *T. tritici* is more prevalent in the Northwest and Pacific Coast areas.

Covered smut may be recognized on the plants by the tendency of the diseased specimens to appear darker in color and for the glumes to

be spread open by the enlarged smut balls. When present in considerable quantity the spores impart a fishlike odor to the wheat and greatly lower its market value. If an appreciable amount of the smut is present in wheat, the Federal grain-grading standards designate the characteristic by labeling the wheat "smutty." This designation invariably results in a lowered price.

Life Cycle of Bunt.—The spores are produced in the caryopsis having been formed there as the organism developed and utilized the plant as a host. A fully developed smut ball consists of the seed coat of the wheat with all other parts replaced by the millions of smut spores. At the time of threshing many of the smut balls break and the scattered spores adhere on the uninfected seeds, particularly in the hairs of the brush. The organisms remain on the seed throughout the storage and unless destroyed are ready to start growth when the wheat is planted. The smut spore germinates on the surface of the seed and produces a promycelium on which are developed sporidia. These sporidia fuse and give rise to a germ tube that enters the young seedling, grows inside of the plant, and destroys all parts of the flower except the seed coat, which it packs closely with a mass of spores.

Favoring Factors.—Covered smut is more of a problem in mild than in cold climates. In the Pacific Northwest the organisms readily overwinter in the soil and provide a source of infection even though clean seed is used. Naturally, the presence of many spores as a result of a severe epidemic in the previous year will favor greater infection from bunt.

Controlling Bunt.—Cultural practices may be of value in control. In the Pacific Northwest where wheat follows a badly smutted crop of wheat, it tends to become more badly infested so that crop rotation is a means of reducing the severity of infection. In the hard red spring wheat belt the organism generally does not overwinter in the soil. The use of clean seed means that there is less danger, since seed that comes from a badly diseased field is certain to carry a high percentage of inoculum.

Some progress has been made in the breeding for resistance to bunt, although many varieties continue to show susceptibility.

Loose Smut of Wheat.—*Ustilago tritici* (Pers.) Rostr. is not so important as the covered smut, as the losses are not so great, nor is the extent of infection so widespread. Generally, it is most prevalent in the more humid wheat areas. The organism seems to find its most favorable environment in the soft red winter area of the eastern United States.

Life Cycle of Loose Smut.—Unlike the covered smut or bunt this disease may result in the complete destruction of the flower parts, leaving only the naked rachis. The infected plants may grow somewhat taller and appear earlier than healthy specimens. Early in the development of the spore masses, the spikes take on a grayish color. Soon

FIG. 41.—*Ustilago tritici*, loose smut of wheat. (*After Heald.*)

the membrane breaks, and the mass of dark spores are released to be carried by the wind. The dispersed spores may find their way to the flowers of near-by healthy plants. The spore ultimately reaches the stigma of the wheat flower, where it germinates, sending an infection tube into the ovary, and develops a very minute plant that remains dormant within the seed. When the infected seed is planted, the smut organism resumes active growth, developing with the plant. When it reaches the flower parts, it replaces them with the mass of spores and completes the life cycle.

Controlling Loose Smut.—Tingey and Tolman[1] have reported on the breeding of wheat for resistance to loose smut. The use of the hot-water method was outlined earlier in this chapter.

Scab of Wheat.—The scab disease is a problem in the humid wheat- and barley-growing sections of the United States. The organism *Gibberella saubinetii* (Mont.) Sacc. primarily infects wheat and barley, but it may occur on the other cereal grains and corn. It not only reduces the yield of grain but seriously lowers the quality and feeding value. Often the kernels that are affected are light and chaffy. The sale of the grain results in a heavy discount on the marker and entails an appreciable loss.

Life Cycle of Wheat Scab.—The scab organism has an interesting life history. It grows abundantly on the crop plants or on straw, chaff, and cornstalks after the crops have been harvested. It often overwinters on cornstalks and straw, and in the spring, ascospores mature under favorable conditions and are discharged to fall on moist plant refuse, where they grow and develop numerous conidia. The ascospores and the conidia may be carried by the wind to the developing plants where they infect the developing seeds. The organisms may live over in the seed and in the following season cause seedling blights under favorable weather conditions.

Seedling blights occur when diseased kernels are planted or when the seedlings develop in scab-infested soil. The fungus attacks the young plants at the time of, and after, germination. In severe cases many of the plants die in the seedling stage, while others that persist may develop stunted plants producing a very small yield.

The head infection develops at the time of flowering. It is common for a part or all of the spikelets on a head to be affected. Under favorable conditions a salmon-pink or reddish-colored fluffy dustlike growth of mold may appear on the spikes. Because of damage to the rachis, it is not uncommon for the kernels in the upper part of the spike to shrink even though not diseased. The diseased kernels tend to wrinkle and to have a rough, flaky or scabby surface with a whitish to pink color.

Favoring Factors.—Scab is favored by periods of warm, moist weather during the flowering period. The organisms cannot develop when it is dry, so scab is rarely found in the western wheat-producing sections. The seedling blights that result from the presence of the disease either on the seed or in the soil are favored by a warm, relatively dry soil. The seeding of wheat on unplowed land where the corn was infested with scab favors the development of the scab organism.

[1] TINGEY, D. C., and B. TOLMAN, Inheritance of Resistance to Loose Smut in Certain Wheat Crosses, *J. Agr. Research*, **48**: 631–655, 1934.

Control of Scab.—With the farming plans common in the corn belt, it is difficult to control wheat scab, and no varieties are available that possess high resistance. The plant breeder has found it extremely difficult to develop varieties that are resistant. The common systems of farming which leave great quantities of crop residues in the fields together with the tendency to prepare seed beds carelessly lead to ideal conditions for the spread of the disease. It is almost certain that a period of wet weather at the time the wheat flowers will bring on severe attacks of scab.

Clean tillage should do much to check wheat scab. When wheat follows corn, it is advisable to make certain that the cornstalks are plowed under. A poor job of plowing tends to aggravate the spread of the disease. It may be desirable to disk the cornfield before plowing to make better coverage possible.

The best of seed should be planted in every case. If there is evidence of scab infection on the grain, it should be fanned thoroughly to remove the lightweight diseased kernels. Next, the cleaned grain should be treated with an organic mercury dust such as New Improved Ceresan, applied at the rate of 1/2 oz. of dust to each bushel of wheat. The procedure recommended is the same as that given earlier in this chapter for the control of covered smut.

Oats

Although the oat is attacked by some of the same diseases as wheat, it generally is not so likely to suffer complete or nearly complete destruction as wheat. The oat by nature of its growth is better able to succeed under a wider range of environmental conditions than is generally true for wheat. In the discussion of the diseases of oats, as well as other crops to follow, attention will be called to similarities in symptoms and methods of control, and thus it will be possible to avoid unnecessary repetition.

Black Stem Rust.—Stem rust (*Puccinia graminis avenae* Eriks. and Henn.) of oats is closely related to the stem rust of wheat. Both organisms have a similar life cycle except as to the host plant. While great damage may occur in some years, the oat plant is not generally so subject to stem rust injury as wheat. However, estimates given in the *Plant Disease Reporter* of the United States Department of Agriculture for the period 1919–1938 indicate an average loss in the United States from stem rust of about 14,000,000 bu. of oats each year. Favoring factors for oat stem rust are similar to those previously outlined for wheat.

Oat stem rust control methods are much the same as those for wheat. Most of the varieties grown in the spring oat area escape because of

early maturity or are resistant to many of the more prevalent races of rust. Federal workers[1] illustrate the progress that has been made and that may be expected in the future from well-planned breeding programs.

Crown Rust.—The organism that derives its name from the crown-shaped teliospores is known botanically as *Puccinia coronata* (Pers.) Cda. During the period 1919–1938, it has been estimated by workers in the United States Department of Agriculture that crown rust in the United States was responsible on an average for losses of nearly 23,000,000 bu. of oats annually. As with stem rust, many races or forms are known to exist.

Life Cycle of Crown Rust.—Like the stem rust, this organism has an alternate host, the buckthorn (*Rhamnus cathartica* and *R. lanceolata.*) Aeciospores are formed on the buckthorn leaves early in the growing season and spread to the growing oat plants. New spores known as *urediospores* develop rapidly and spread the infection to other plants during favorable conditions. This stage is followed by the development of teliospores which carry the organism through the winter. In the spring the teliospores germinate and infect the buckthorn, thus completing the life cycle. In the regions of mild climate the urediospores of crown rust are orange-yellow in color and do not conspicuously rupture the leaf surface. Stem rust urediospores, on the other hand, are brick red in color and conspicuously rupture the leaf and stem surface.

Control of Crown Rust.—For many years desirable varieties of stem rust resistant oats have been grown extensively by the farmer, but only comparatively recently has the plant breeder been able to give him varieties that are resistant to crown rust as well. The discovery of the crown rust resistant varieties Bond and Victoria gave great impetus to the improvement program. Both Bond and Victoria were crossed with available stem rust resistant varieties to produce varieties resistant to both stem and crown rusts. Examples are Tama and Vicland. Early seeding of oats is also desirable, since an early crop normally escapes the dangers of crown rust infection.

The Smuts of Oats.—It is known that the loss from oat smuts in the United States is great, but it is extremely difficult to estimate the damage accurately, since their effect is generally distributed throughout the field and the farmer frequently is unaware of the severity of the damage that has occurred to his crop. Loose smut [*Ustilago avenae* (Pers.) Jen.] and covered smut [*Ustilago levis* (K. and S.) Magn.] are similar in appearance

[1] Murphy, H. C., T. R. Stanton, and F. A. Coffman, Breeding for Disease Resistance in Oats, *J. Am. Soc. Agron.*, **34**: 72–90, 1942.

and characteristics. In a heavy infestation, many of the oat flowers are replaced by a mass of black spores and production is greatly reduced.

Life Cycle of Oat Smut.—In general, the life cycles of the two smuts are alike. The spores that are borne in the flower parts lodge on the seed of the nondiseased grain and remain there until planted. When the seed is planted, the spore germinates and its mycelium or sporidia pene-

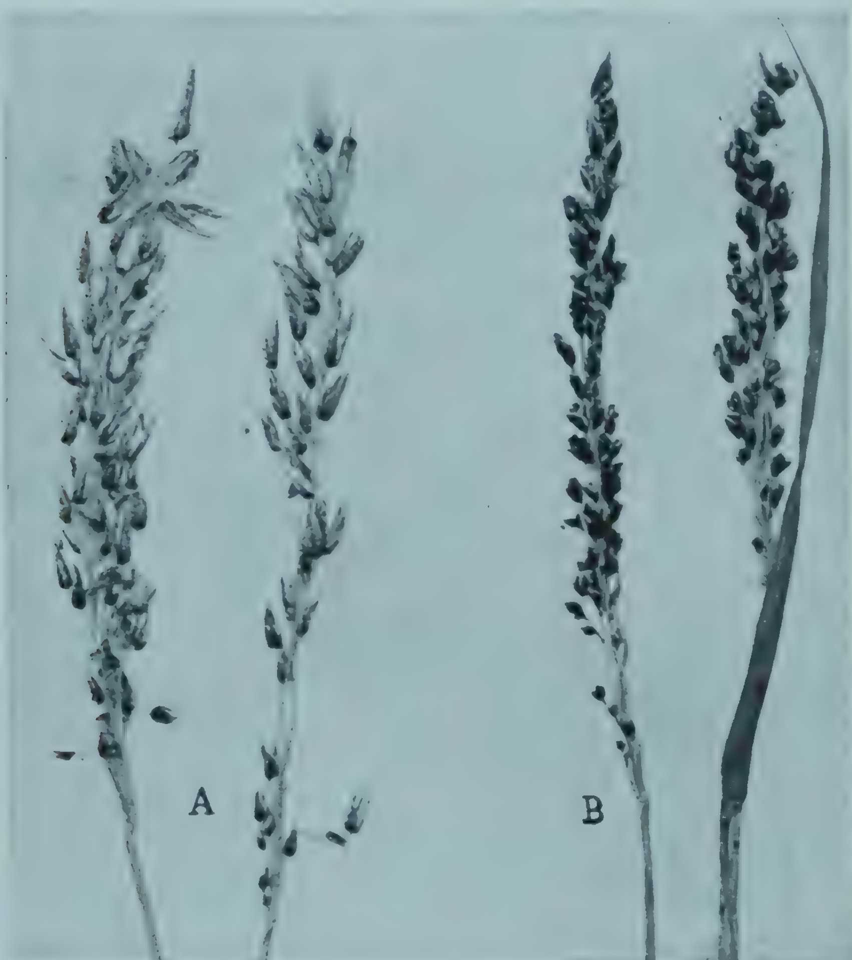


FIG. 42.—Oat smuts. *A*, kernel smut, (*Ustilago levis*); *B*, loose smut, (*U. avenae*). (*After Heald.*)

trate the young seedling. Chlamydospores, especially in loose smut, usually germinate and the mycelium enters the lemma, pala, and outside the caryopsis. In most cases this is the method of overwintering, and then in the spring the organism enters the young seedling. It develops within the growing plant, much as the loose smut organism of wheat, and, upon reaching the floral parts, destroys and replaces them with its numerous spores.

Control of Oat Smut.—The breeding programs of most oat investi-

gators have included the control of the smuts. Important smut resistant varieties used in breeding include Victoria, Markton, Navarro, Bond, and Black Mesdag. Marked success has been obtained through the use of these varieties in breeding varieties that are practically free from infection. Varieties that have proved of great promise in the corn belt include Vicland, Tama, Boone, Vikota, Cedar, and Control. In the South, Fultex, Ranger, and Rustler have shown considerable promise. Several crosses between Lee and Victoria appear to possess the vigor and winter hardiness of Lee combined with the smut and crown rust resistance of Victoria.[1]

Helminthosporium "96."—This appears to be a new fungus disease of oats caused by a species of Helminthosporium recognized only recently and identified at present as Helminthosporium "96." Extensive damage was caused in susceptible varieties in 1946 by this disease in an area from Iowa and Minnesota eastward to the Atlantic Coast.

Comparatively little is known about the disease. All parts of the oat plant may be affected, resulting in seedling blight, crown rot, leaf spot, blackening and brittleness of stems, and kernel blight. Damage may vary from slight to complete loss. The fungus may be carried over winter on infected seed and plant debris.

The chief source of primary inoculum appears to be diseased seed. Leaf spots on infected seedlings furnish inoculum for further spread of the fungus. Seed treatment with New Improved Ceresan gives some degree of control. However the use of resistant varieties seems to be the most feasible means of control. All varieties and strains having the crown rust resistant variety Victoria as a parent, such as Tama, Boone, and Vicland, appear to be highly susceptible. The new varieties Clinton, Benton, Bonda, Mindo, and Eaton are resistant, as are many of the older varieties.

Barley

Barley is not so extensively grown as wheat or oats, but in the regions where it is adapted the disease problems are of great importance. Losses from such a disease as fusarial head blight may be so great that the crop is a failure. In some areas barley diseases have been so serious in certain years that the farmers have tended to discontinue the growing of the crop.

Stem Rust of Barley.—The organisms attacking barley are *Puccinia graminis* (Pers.) *tritici* Eriks. and Henn. and *P. graminis* (Pers.) *secalis*

[1] Murphy, H. C., T. R. Stanton, and Harland Stevens, Breeding Winter Oats Resistant to Crown Rust, Smut, and Cold, *J. Am. Soc. Agron.*, **29**: 622–637, 1937.

Eriks. and Henn. As a general result stem rust does not do much damage to barley, but occasionally heavy losses occur when conditions favor an epidemic. The life cycle and general characteristics are the same as those given for wheat.

Scab of Barley.—The organism *Gibberella saubinetii* (Mont.) Sacc. is the same as that attacking the other cereals and corn. In the humid barley-producing areas it frequently causes great losses, especially in wet seasons which favor its spread. Besides the reduction in yield, which may result in a total loss, the quality of the grain is greatly affected. Barley that contains more than 2 per cent of blighted kernels is graded as Blighted Barley and usually takes a price discount. If the percentage is more than 4 per cent, the grain cannot be graded as Malting Barley. Barley affected by the scab organism is poisonous to pigs, as has been shown by Christensen and Kernkamp.[1] Hogs usually refuse to eat infected grain but if forced to eat it will become sick and, if feeding is continued, die from the toxins developed in digestion.

The life cycle and the favoring factors are the same as those given earlier in the chapter for the wheat scab.

Controlling Barley Scab.—Sanitation is of great importance, as was indicated in the discussion of wheat scab. In the corn belt, it is common to seed barley on land that has been in corn. It is very important that a good job of plowing be done to ensure the turning under of all cornstalks which may carry the inoculum and thus spread it to the barley.

The use of clean seed treated with organic mercury dusts will aid in the control of the seedling blights. The farmer should avoid growing barley after barley, wheat, or corn.

The breeding of disease-resistant varieties offers some promise, and programs are under way in the humid-area barley states.

Loose Smut of Barley.—*Ustilago nuda* (Jens.) K. and S. is a serious disease in the barley areas. Like loose smut of wheat, the extent of the damage is not generally appreciated by the grower.

Life Cycle of Loose Smut.—The life cycle of loose smut of barley is similar to that of wheat. The organisms entirely destroy the flowers, leaving only the naked rachis. The spores are carried by the wind to the flowers of healthy plants, where they develop and remain within the seed in a resting condition until the seed is planted, when they develop with the plant and destroy the flower parts.

Controlling Loose Smut.—The hot-water treatment is necessary to destroy the organisms within the seed, as outlined earlier in this chapter.

[1] Christensen, J. J., and H. C. H. Kernkamp, Studies on the Toxicity of Blighted Barley to Swine, *Minn. Agr. Expt. Sta. Tech. Bull.* 113, 1936.

Breeding for disease-resistant varieties is being carried on by the plant breeders and pathologists.

Covered Smut of Barley.—*Ustilago hordei* (Pers.) K. and S. is found in nearly all barley-producing areas and frequently causes severe losses.

Life Cycle of Covered Smut.—The spores are carried on the surface of the threshed seed, having been lodged there as a result of the breaking of infected smut balls. The organism produces a mycelium which infects the growing plant and finally produces a mass of spores in much the same way as covered smut of oats.

Controlling Covered Smut.—The seed treatment is the same as that given earlier for covered smut of wheat. Considerable progress has been made in the breeding of resistant varieties.

Barley Stripe Disease.—*Helminthosporium gramineum* Rabh. is generally present in the humid and subhumid barley-producing areas. It is particularly serious in the spring barley producing sections of America. Christensen and Graham[1] reported that infection in Minnesota commonly reached 5 to 10 per cent.

Cycle of Barley Stripe.—The flowers are infected at the time of blooming, while the seedlings are frequently infected at the time of germination. Healthy plants are infected by spores from the diseased plants, which may be recognized by a dead area that runs longitudinally with the leaf to form a stripe. The spores are carried on the seed to produce infection the following year.

Control of Barley Stripe.—The use of organic mercury dust seed treatments has proved effective. The breeding of resistant varieties offers promise, as resistance has been obtained in some cases.

Rye

The rye plant normally does not suffer from so many diseases as most of the other cereal crops. It is not uncommon for rye to be practically free of the rusts and to yield normally. This freedom from diseases is one of the reasons why rye is so widely grown under rather adverse conditions.

Stem Rust of Rye.—*Puccinia graminis* (Pers.) *secalis* Eriks. usually is not of great importance. Probably the reason for less damage to rye than to the other cereals is its extreme earliness, which generally enables it to escape damage.

[1] Christensen, J. J., and T. W. Graham, Physiologic Specialization and Variation in *Helminthosporium gramineum* Rabh., *Minn. Agr. Expt. Sta. Tech. Bull.* 95, 1934.

The life cycle of stem rust on rye is much the same as that outlined for wheat stem rust earlier in the chapter.

Ergot of Rye.—The ergot disease *Claviceps purpurea* (Fr.) Tul. attacks rye and the other cereals. Generally, it is much more prevalent on rye than on the other grain crops. In addition to reducing the yield of grain, the presence of more than 0.3 per cent of ergot bodies in the threshed grain results in a market designation of "ergoty" with a consequent discount in the price paid. The ergot bodies are especially undesirable since they are poisonous in nature, causing abortion if fed to livestock.

Life Cycle of Ergot.—The ergot bodies, which actually are purple to black sclerotia, fall to the ground when mature or are planted with the rye kernels. These sclerotia germinate and produce spores which are carried to the flowers of the rye plant where they develop the honeydew stage, conspicious by its thick, sticky exudate that attracts insects, which in turn spread the infection. With maturity, the dark-colored sclerotium replaces the kernel. Usually it is longer than the kernels and may be readily recognized, as it extends well beyond the glumes.

Controlling Ergot.—Clean cultivation and crop rotation aid greatly in the control of this disease. Frequently, the weedy grasses such as quack grass are infected on the borders of the field and thus provide inoculum. These plants should be cut and destroyed. All volunteer rye that remains over in the field should be destroyed. Thorough cleaning of the seed to remove all ergot bodies (sclerotia) should be practiced. In some sections, the same organism may develop in barley and wheat, and these crops may serve as sources of infection.

Flax

The flax crop provides one of the most dramatic illustrations of successful disease control through science. In the early agricultural history of America, it was believed that flax was very "hard on the soil," that it exacted so many nutrients that it could be grown but once and then must be planted on virgin soil. The work of Dr. H. L. Bolley of the North Dakota Agricultural Experiment Station led to the true solution: that the lowered yields were the result of the soil becoming infected with the flax wilt organism, which more or less completely destroyed the crop. Bolley showed that through selection it was possible to secure varieties of flax that resisted the flax wilt and produced satisfactory crops.

Flax Wilt.—The disease *Fusarium lini* Bol., as previously indicated, nearly eliminated flax growing in America. Today farmers grow resistant varieties and have little or no fear of the disease.

Life Cycle of Flax Wilt.—The organism, as has been stated, lives over in the soil, and when flax is planted it enters the tissues of the young seedling and the vascular system, causing plants to wilt and die. Many of the susceptible plants are destroyed in the seedling stage. Once the disease has been introduced into the soil, it remains for several years and quickly destroys the plants of susceptible varieties.

Controlling Flax Wilt.—The dramatic story of the work of Bolley in pointing the way to the solution of this problem has been well portrayed by Dillman.[1] Proper crop rotation, thorough seedbed preparation, and the practice of early planting have aided in the control of wilt. Even a resistant variety may show considerable injury if grown under unfavorable conditions such as result from delayed planting.

Flax Rust.—*Melamspora lina* (Pers.) Lev. is a widely distributed disease that may or may not cause serious damage, depending upon the conditions that favor its development. When present in epidemic form, serious yield reduction may occur.

Life Cycle of Flax Rust.—This fungus disease goes through all its cycle on the flax plant. After its rest period on the stubble, the teliospores germinate to produce sporidia which attack the young flax plants. From the original infection, secondary infections may occur throughout the active growing stage of the plant. Usually with the maturity of the flax plant the telial stage develops, and the organism is carried over to produce infection the following year.

Controlling Flax Rust.—It is evident from the life cycle of the disease that sanitation is important. Proper crop rotation and the plowing under of all flax stubble is of value. At present there are varieties that are immune to all races so far discovered.

Corn

Because of its extreme importance as a major agricultural crop, the diseases of corn are of great significance. There are so many diseases of corn that the discussion here must of necessity be limited to those of greatest importance. From a production viewpoint, the American student is most concerned with the seedling diseases and their control, as there are several that may cause great losses both in the seedling and in the mature plant stages.

Corn Smut.—*Ustilago zeae* (Beckm.) Ung. is found wherever corn is an important crop. Under severe conditions, losses as high as 5 per cent have been reported. It may be recognized by the galls or tumors that

[1] Dillman, A. C., Improvement in Flax, *U.S. Dept. of Agr., Yearbook of Agriculture,* 1936.

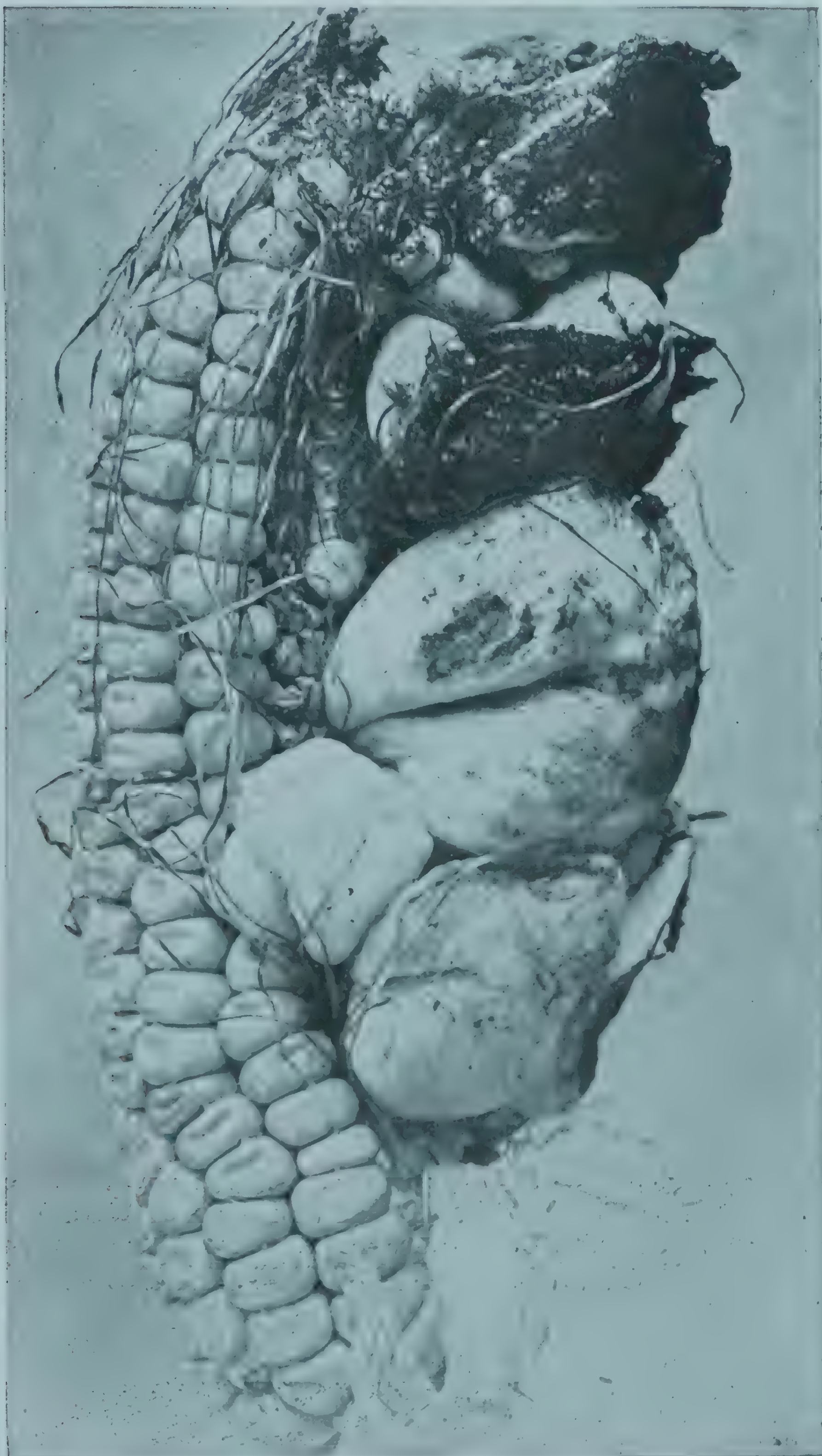


FIG. 43.—*Ustilago zeae* on an ear of corn. (*After Heald.*)

occur on all parts of the plant above the ground, particularly on the stalk in the leaf sheath. When mature, the galls are filled with a mass of black spores.

Life Cycle of Corn Smut.—The smut galls contain the many spores which are spread widely when ruptured. Many may be carried to the feeding places where they frequently lodge in the farm manures. When the manure is hauled to the field, the organisms germinate following favorable conditions. Also, many of the spores that live over in the soil may develop into sources of infection. Following germination a threadlike structure called a *promycelium* develops and within a short time produces sporidia; these are readily carried by the wind to lodge on the growing tissue of corn plants where they germinate and develop into the tumorlike growths commonly referred to as *smut galls.* Infection may occur wherever the organism can gain entrance into the young tender tissue. Others may lodge in the leaf sheath at the axil of the leaf or in the tassel. Within 1 to 3 weeks infection occurs and the galls result. When conditions are favorable, the rate of spread may be great.

Controlling Corn Smut.—Crop rotation is important, and a good job of plowing under the stalks and other refuse aids greatly in checking the spread of smut. Some evidence indicates that the application of fresh manure as a top dressing to cornfields favors smut development. Progress has been made in the development of resistant varieties, but resistance is not so clear cut as is true for certain other diseases.

Root Rots and Seedling Blights.—Several of these diseases are known to cause great losses to corn, not only in the seedling but also in the more mature plant stages. The extent of losses is difficult to determine with accuracy, but many investigators believe that they may range from 5 to 50 per cent under favorable conditions. There are many organisms that attack the corn seedling and growing plant, but here only the more important will be discussed.

Gibberella Root Rot.—The corn disease *Gibberella saubinetii* (Mont.) Sacc. is the same as that which attacks several of the cereal plants and has been discussed earlier in this chapter in the section on wheat diseases. Under severe epidemics, heavy infection may occur, and losses occur in the seedling stage.

Life Cycle of Gibberella.—The life cycle of this disease was presented earlier in the chapter. In corn, it develops on plant residues, particularly corn stalks remaining in the field. The spores from infected wheat heads or plant residues are carried to growing corn plants, attacking any part of the plant. Later in the season, parathecia may develop near the nodes of infected cornstalks, and under certain conditions the disease

may cause ear rot. The seed of plants affected may carry the organism to the field and result in severe seedling blight and root rot.

Controlling Gibberella.—Sanitation to plow under all refuse and crop rotation are valuable. The use of organic mercury dusts aids in the control of the disease where the seed is infected. Plant breeders have

Fig. 44.—Normal ear of corn and two ears affected with dry rot. (*From 22d Annual Report, Nebraska Agricultural Experiment Station. After Heald.*)

made progress in the development of inbred lines that are resistant to Gibberella both in the seedling and the growing plant stages.

Diplodia of Corn.—This disease, like Gibberella, attacks the corn plant both in the seedling and active growing stages and may cause great losses in yield, reduction, and lowered quality of harvested corn.

Life Cycle of Diplodia.—*Diplodia zeae* (Schw.) Lev. overwinters on corn plants and rotted ears left in the field. Where the infection is severe, many apparently healthy kernels will carry the disease. A severely infected ear is reduced to a charlike mass with a matting of

mold that gives the ear a grayish to black appearance. In lighter infestations the kernels may show no visible infestation, but the organisms may be observed as white flaky masses on the cob. The presence of the small black fruit bodies known as *pycnidia* is a means of identifying the disease. These may occur on the ear or on the cornstalk. The pycnidia produce pycnospores which are carried to the corn plant, frequently falling in the axil of the leaf sheath where they develop the infection. Throughout the season new pycnospores are developed to spread the infection. On the leaf sheaths the disease produces red to purple colored spots which appear after tasseling. The presence of the disease on a mature cornstalk may be recognized by the small black pycnidia on the surface.

Control of Diplodia.—The control measures for diplodia are the same as those given for Gibberella.

Bacterial Wilt, or Stewart's Disease.—This is a bacterial disease, as the name indicates, which does much damage to sweet corn under favorable conditions and may when present cause damage to field corn.

Life Cycle of Bacterial Wilt.—The disease infests the fibrovascular system of the plant, clogging it so that the transpiration stream is stopped. A cross section of an infected stalk will show the yellow-colored diseased bundles from which a yellow exudate issues after cutting. In more mature plants, the diseased bundles are dark in appearance. The organism appears to be carried on the seed. With the germination of the seed, the bacteria gain entrance into the vascular system. Later infections may occur through the leaves or buds of young plants when conditions are favorable. It has been demonstrated that insects may be responsible for the spread of the disease.

Controlling Bacterial Wilt.—The practice of sanitation to destroy old cornstalks from infected fields and the use of crop rotation aid in control. The breeding of corn varieties resistant to the disease has proved promising.

Other Corn Diseases.—Several other corn diseases are of importance, attacking either the seedling or the growing plant or both. Crop rotation, sanitation, tillage, seed treatment, and breeding all aid in their control.

Review Questions

1. What plant diseases are prevalent in your community?
2. How serious are plant diseases in America?
3. What is done on your home farm to control diseases?
4. What diseases attack wheat?
5. Explain the part played by the alternate host in the life cycle of black stem rust.

6. What is a physiologic race?
7. How does red rust differ from black rust on wheat?
8. What are plant breeders doing to control plant diseases?
9. Why is it essential that the plant breeder and the plant pathologist work closely together in disease control?
10. How does leaf rust of wheat differ from black stem rust?
11. What is bunt?
12. Why is loose smut of wheat or barley so difficult to control by seed treatment?
13. What cultural factors may aid in the control of bunt?
14. What environmental conditions favor wheat scab?
15. How does crown rust differ from black stem rust?
16. Name disease-resistant oat varieties developed by breeding.
17. What are the most serious diseases of barley?
18. What can the farmer do to control barley scab?
19. How does barley scab affect the market value of the grain?
20. Why is sanitation of value in the control of ergot?
21. What grain crops may be attacked by ergot?
22. Why did the early settlers always grow flax only on new land?
23. What is corn smut?
24. What crops are attacked by *Gibberella saubinetii?*
25. What is the value of seed treatment in the control of seedling diseases?

References

BRENTZEL, W. E.: The Black Point Disease of Wheat, *N. D. Agr. Expt. Sta. Bull.* 330, 1944.

———: Studies on Seed Treatments for Cereal Crops, *N. D. Agr. Expt. Sta. Bull.* 331, 1944.

BRYAN, W. E.: Breeding for Smut Resistance in Arizona-grown Wheat, *Ariz. Agr. Expt. Sta. Tech. Bull.* 66, 1937.

DICKSON, JAMES G.: "Diseases of Cereal and Forage Crop Plants of the Northern Part of the United States," Burgess Publishing Co., Minneapolis, 1940.

———: Scab of Wheat and Barley and Its Control, *U. S. Dept. Agr. Farmers' Bull.* 1599, revised 1942.

HARRIS, R. D., L. D. SIBBITT, and W. E. BRENTZEL: Blight and Other Damage of Durum Wheat in 1940, *N. D. Agr. Expt. Sta. Bull.* 296, 1941.

HAYES, H. K., and F. R. IMMER: "Methods of Plant Breeding," McGraw-Hill Book Company, Inc., New York, 1942.

HEALD, F. D.: "Introduction to Plant Pathology," 2d ed., McGraw-Hill Book Company, Inc., New York, 1943.

HOLBERT, J. R., W. L. BURLISON, BENJAMIN KOEHLER, C. M. WOODWORTH, and G. H. DUNGAN: Corn Root, Stalk and Ear Rot Diseases and Their Control through Seed Selection and Breeding, *Ill. Agr. Expt. Sta. Bull.* 255, 1924.

LIVINGSTON, J. E.: Reduce Black Stem Rust of Wheat, Oats, Barley, and Rye, *Neb. Agr. Ext. Circ.* 1802, 1943.

———: Important Diseases of Corn in Nebraska, *Neb. Agr. Ext. Circ.* 1804, 1945.

SMITH, RALPH E.: Diseases of Field Crops, *Calif. Agr. Ext. Circ.* 121, 1941.

SPRAGUE, RODERICK: Rootrots of Cereals and Grasses in North Dakota, *N. D. Agr. Expt. Sta. Tech. Bull.* 332, 1944.

CHAPTER VIII

INSECT PESTS OF GRAIN CROPS

The insect pests that attack grain crops are responsible for losses of millions of dollars each year in the United States. Nearly everyone has seen evidence of the great damage that may be done, but many losses are not so evident to the casual observer. While a crop such as sweet corn may produce a fair yield, the lowered quality due to the attacks of the corn ear worm may greatly reduce the quality and thus lower the market value. It is extremely difficult to evaluate such losses properly in terms of dollars. Peairs[1] has estimated that the annual damage done by insects each year from 1930 to 1939 totals $1,232,500,000. A considerable part of this total was the result of injury to the grain crops either while growing or in storage after harvest.

The present chapter includes a discussion of the more important insects of grain crops with their characteristic type of damage and methods of control. In no manner is this material planned to substitute for a course in entomology, but rather to present supplementary information essential to a well-rounded treatment of grain-crop production.

GRASSHOPPERS OR LOCUSTS

Several species of grasshoppers are destructive to crops. These are the pests that in the early days of our agricultural history appeared like clouds and destroyed all living green plants within a few hours. The principal species that are likely to cause much damage to grain crops are (1) the red-legged grasshopper (*Melanoplus femur-rubrum* De Geer), (2) the Rocky Mountain or lesser migratory grasshopper (*M. mexicanus spretus* Welsh), (3) the two-lined grasshopper (*M. bivittatus* Say.), (4) the clear-winged grasshopper (*Camnula pellucida* Scudder), (5) the differential grasshopper (*M. differentialis* Thos.), and (6) the Carolina grasshopper (*Dissosteria carolina* L.).

Characteristics of Grasshoppers.—The six species listed possess certain well-defined characteristics that serve to differentiate them from one another.

The Red-legged Grasshopper.—This species is small, generally brown-

[1] Peairs, L. M., "Insect Pests of Farm, Garden, and Orchard," 4th ed., John Wiley & Sons, Inc., New York, 1941.

ish red above and yellow below, with the rear legs a pink red with black hairs or spines. The hind wings are colorless.

The Rocky Mountain Grasshopper.—This species closely resembles the red-legged species. Usually the legs are not as bright pink; it has a spot of black on the neck or collar and possesses certain morphological differences that can be determined readily by a trained taxonomist. This grasshopper has been referred to as migratory because of the tendency of the nymphs to migrate from their breeding grounds to new feeding areas. When numerous, the adult tends to fly long distances in its search for new feeding areas.

The Two-lined Grasshopper.—The adult is a large insect, 1 to 1½ in. long; the upper part of its body is olive in color with a yellow stripe extending lengthwise along each side.

The Clear-winged Grasshopper.—This important species may be recognized by its nearly transparent rear wings, whereas the front wings are blotched with brown.

The Differential Grasshopper.—The adult is usually yellow with transparent, glossy black wings and averages about 1½ in. in length. The hind legs are normally marked with yellow and black bars on the sides of the thighs.

The Carolina Grasshopper.—The adult is medium to large and has plain pepper-and-salt color, varying from grey through yellowish to a red color, depending upon the soil where it is found. The back wings are nearly black with margins of yellow.

Life Cycle of Grasshoppers.—In general, the life cycles of the foregoing species of grasshoppers are very much alike. The adult insect lays its eggs in the late summer or early fall in masses of 20 to 100 or more deposited in the soil. Here the eggs pass the winter, and the young hatch with the coming of spring to emerge in their search for food. Later in the season the adult appears, and it feeds throughout the season until the coming of cold weather. When present in great numbers they may destroy entire crops within a few days. During the late summer the adult will lay many eggs providing for a great increase in population with favorable conditions, of which the most important is a dry soil.

Controlling Grasshoppers.—The fall plowing of soil may be of value in destroying many of the grasshopper eggs. However, the most effective control has come from the use of poison baits to destroy those insects which appear. Since the broods tend, under favorable conditions, to become larger and larger, the lack of control may lead to such serious infestations that entire crops may be destroyed.

Several formulas may be used for the poison bait but most are based on the use of a poison mixed with bran and other materials that may be attractive to the insects. The following mixture, as suggested by Parker,[1] is generally typical of poison baits:

Mill-run Bran and Sawdust

Mill-run bran, mixed feed, or shorts	25 lb.
Sawdust (three times bulk of mill-run bran)	3½ bu.
Liquid sodium arsenite (32 per cent arsenious oxide)	½ gal.
Water	10–12 gal.

FIG. 45.—Showing aversion of the grasshopper for the sorghums. Left, field corn almost entirely destroyed. Right, grain sorghum. (*Courtesy of H. C. Severin, South Dakota Agricultural Experiment Station.*)

In recent years sodium fluosilicate has practically replaced sodium arsenite as the poisoning agent.

The bait may be mixed on any tight surface by spreading the sawdust in a layer 6 to 8 in. deep. The bran is then scattered over the sawdust, and the two materials are mixed thoroughly. The mixture of water and chemical is splashed over the dry mixture in three applications and turned with shovels after each wetting. It is important that a good job of mixing be done to avoid any lumps.

The poison bait is spread thinly in the infested fields at the rate of 10 to 20 lb. (wet basis) per acre. Care must be taken to secure a good distribution. Usually this can best be obtained by hand applications,

[1] PARKER, J. R., Grasshoppers and Their Control, *U.S. Dept. Agr. Farmers' Bull.* 1828, 1939.

although various types of mechanical spreaders have been used to advantage.

The poison is given to the grasshoppers soon after sunrise, if they are on the ground, usually between 6 and 10 A.M. When the insects are migrating, the bait may be spread at any time.

Extreme care must be taken to guard livestock from access to the bait. Every year valuable animals are lost from the careless use of the poison. Bait that is spread properly cannot be picked up by livestock in sufficient quantities to cause poisoning.

The breeding of crop varieties resistant to insects offers some promise. Brunson and Painter[1] in the 1936 grasshopper outbreak noted outstanding differences in the injury of corn varieties, top crosses, and hybrids. In one set of trials with hybrids, the defoliation ranged from 4 to 59.8 per cent.

WHITE GRUBS

(*Phyllophaga* or *Lachnosterna* spp.)

The white grub is widely distributed through the crop-producing sections where the adult form is known either as the May beetle or the June bug. The larva or grub feeds primarily on the roots of grass plants and frequently does great damage to corn. The beetle usually does but little damage but may be conspicuous by its attacks on the leaves of trees, particularly oaks.

Life Cycle of the White Grub.—The adult beetle, a brown-colored insect about 1/2 in. in length, emerges from the soil early in the summer to feed and mate. These flights usually occur during the night. With the coming of daylight they return to the soil where the females lay their eggs one to several inches below the surface. Within 2 to 3 weeks the eggs hatch and the young larvae begin to feed on the roots of plants with which they may come in contact. The grubs live all summer on plant roots, reaching a size of about 1/2 in. by fall when they move downward in the soil beneath the frost line. Here they pass the winter until the weather warms, when they again come to the upper levels of the soil to continue their feeding on plant roots through the entire second season. Again as cold weather approaches, the grubs, now about 1 in. long, move down below the frost line. The following spring they move upward after having changed to the pupal stage some 6 to 8 in. below the surface. The pupa changes to the adult form, the beetle, to pass the winter

[1] Brunson, A. M., and R. H. Painter, Differential Feeding of Grasshoppers on Corn and Sorghums, *J. Am. Soc. Agron.*, 30: 334–346, 1938.

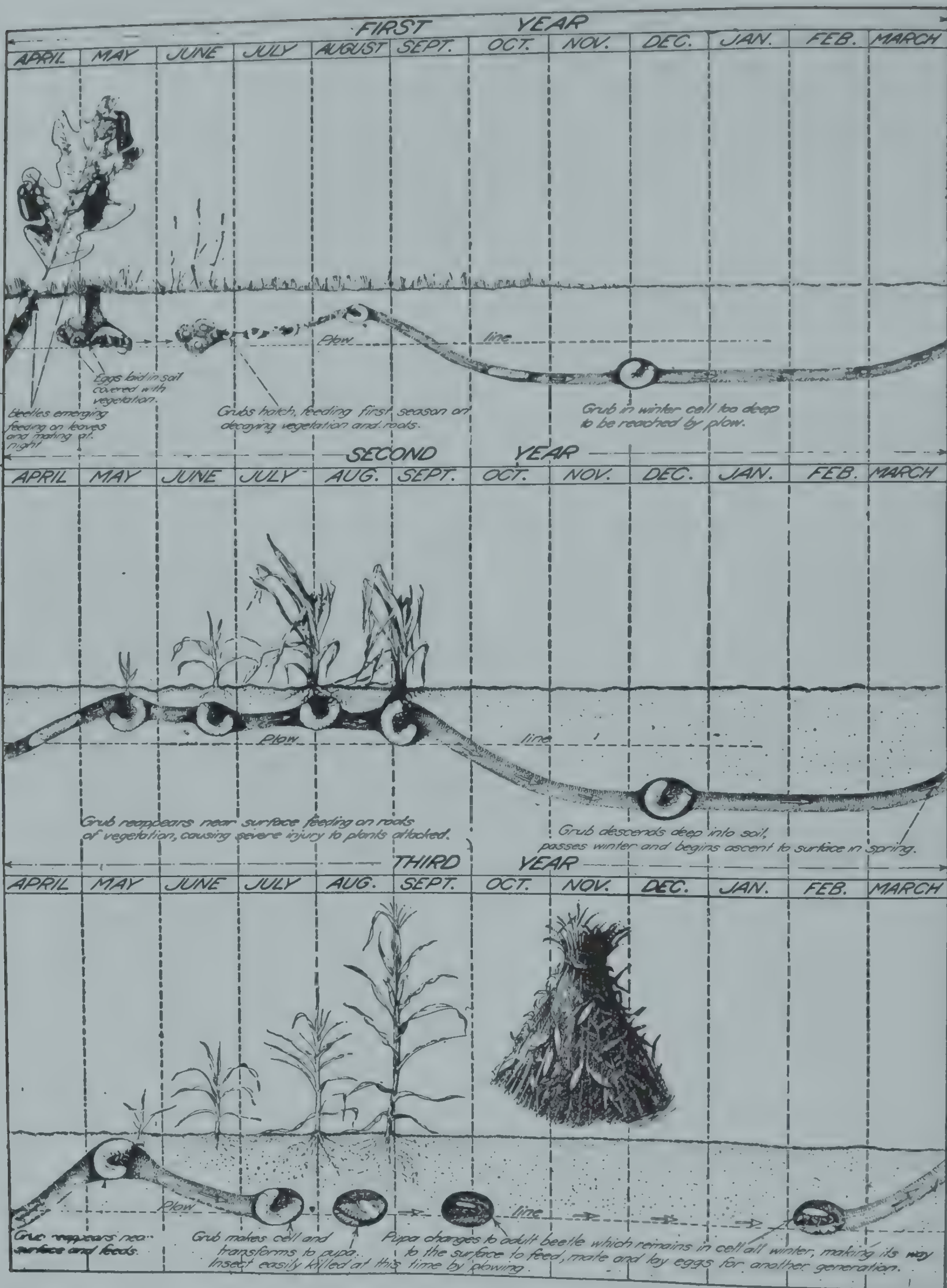


FIG. 46.—Life cycle of the white grub. (*Courtesy of the Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture.*)

of the third season in the soil. It emerges the following spring and summer to feed on tree foliage and to lay eggs in the soil and thus complete the cycle. Many species of the beetles are known, but those requiring 3 years to complete their life cycle are the most common.

During the development of the grubs they are voracious eaters and are especially serious when the numbers become great in the cornfields, where complete crop destruction may result.

Controlling White Grubs.—Since the grub normally requires 3 years for the completion of its cycle, it is evident that there must be three different broods if adults appear each year. This is true, and it follows that one brood may be more serious than another. Planning to have a field in such a crop as clover instead of corn in the year when the largest brood appears is a means of control. The population of the different broods is known by the state entomologists, and forecasts may be made enabling the farmer to plan his cropping accordingly.

Early and deep fall plowing will aid in the destruction of many of the pupae and grubs as well as making it possible for birds and other predators to destroy many more. Thorough disking of the soil in the fall and spring will aid in bringing about further destruction of the insects.

Hoegemeyer,[1] in corn-breeding studies, obtained differential resistance to grub injury in Kansas. He stated that "the single crosses having the least root injury when combined gave the double cross combinations which were least injured, whereas, the more severely damaged single crosses in combination gave double crosses which were more severely damaged by white grubs."

THE CORN ROOTWORMS

The larvae of these insects attack the roots of the corn plant and frequently cause serious damage. Under some conditions the adult beetle may feed on the foliage and silks of corn.

The most important species are (1) the southern corn rootworm (*Diabrotica duodecimpunctata* Fabr.), and (2) the western corn rootworm (*D. longicornis* Say.).

The Southern Corn Rootworm.—This insect is often referred to as the *spotted cucumber beetle* because of the 12 black spots on the back of the yellow or yellow-green beetle. The larvae burrow into the roots and lower parts of the cornstalk. The adult beetle hibernates under plant refuse or at the bases of plants. The larvae that hatch burrow into the plant roots and underground parts of the stems, reaching the adult stage during the summer.

The Western Corn Rootworm.—This is a serious pest of the corn plant in much of the corn belt. The adults are green to green-yellow

[1] Hoegemeyer, Leonard C., An Association of Root Injury by White Grubs (*Phyllophaga* spp.) and Lodging of Crossbred Strains of Corn, *J. Am. Soc. Agron.*, 33: 1100–1108, 1941.

in color. Like the southern corn rootworm, the larvae burrow into the underground portions of the corn plant. The adult lays its eggs in the fall in the soil near the roots of the corn plant, and nearly all die with the first frost. The eggs hatch in the spring, and the larvae attack the underground parts of the corn plant. The adult stage is reached again in the middle of summer and completes the cycle. Often the adult beetles feed on the corn plant, particularly on the silks of the ear.

It is difficult to control the southern corn rootworm as the eggs are often deposited after the corn has germinated. Late planting of the corn has proved of some value in making it possible for the plants to escape infestation. Crop rotation has proved of no value. The insects may be more serious in wet seasons, which seem to favor their development. Bigger *et al.*[1] obtained a differential response in inbred lines to larvae attack, and the resistance was shown to be heritable.

The western corn rootworm is rather easy to control since it attacks corn only. With crop rotation the insect is unable to do very effective damage.

THE WIREWORMS

The wireworms, of which there are many species of the order *Coleoptera*, are very destructive, damaging corn, the small grains, and many other crops. It is not uncommon for the wireworm to destroy the seed before it has an opportunity to germinate. Later attacks may result in the insect burrowing into and feeding on the underground parts of the plants.

Life Cycle of the Wireworm.—The adult, often known as a *click beetle*, is a hard-shelled gray to black beetle. The females are most injurious, as they are heavy feeders and lay their eggs in the soil, usually near the roots or grasses. These adults, which live 10 to 12 months, lay many eggs that hatch within a few days to a few weeks. The larvae may live 2 to 6 years in the soil. The larvae of many species are hard-skinned dark-brown wirelike worms $\frac{1}{2}$ to $1\frac{1}{2}$ in. in length. They spend varying lengths of time before changing to the pupal stage and then to the adult stage.

Controlling Wireworms.—The wireworm is difficult to control. The use of such crops as the soybean in the rotation is of value in checking the spread of the wireworm. Clean cultivation with deep plowing early in the fall has been of some value.

[1] Bigger, John H., Ralph O. Snelling, and Ralph A. Blanchard, Resistance of Corn Strains to the Southern Corn Rootworm (*Diabrotica duodecimpunctata* F.), *J. Econ. Entomol.*, **34**: 605–615, 1941.

CUTWORMS

There are many species of cutworms, which belong to the order *Lepidoptera*. The insect is most widely known for its tendency to cut off plants just above or below the surface of the soil, although its attacks may include damage to the roots and underground parts of the plant.

Life Cycle of Cutworms.—Usually the insect overwinters in the larvae stage under plant refuse or in grassy areas. With the coming of spring the larvae feed until early summer, when they change to the pupal stage and later to the adult or moth stage. The adult lays her eggs on the stems of plants or on the bare soil. Within 2 days to 2 weeks the eggs hatch and the larvae that develop usually feed at night, hiding during the day.

Controlling Cutworms.—Crop rotation is of some aid in the control of the cutworms since they tend to become well established in sod crops. If corn follows sod, the land should be plowed deep in the fall to destroy as many insects as possible. The destruction of refuse and weeds in the cornfield will help to check the increase of the cutworm. While it may be destroyed with a poison bait, this is impractical under field conditions.

FIG. 47.—The damage done to ears of corn by the corn borer. (*Courtesy of the Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture.*)

EUROPEAN CORN BORER

Few insects have received the publicity or have been studied more thoroughly in efforts to learn control measures than the European corn borer. First discovered on the eastern coast of America in 1917, the borer relentlessly progressed westward until it reached the heart of the corn belt in 1943. Although it is known as the corn borer, the insect attacks most of the herbaceous plants as well as corn. It receives its name from the fact that it was introduced into this country from Europe.

Life Cycle of the Borer.—*Pyrausta nubilalis* Hubner is characterized by a flesh-colored larva with small round brown spots. These worms, $^3{}_4$

to about 1 in. in length, are voracious feeders and burrow in all parts of the corn plant including the ear. The adult female moth is pale yellow-brown with irregular darker wavy bands of color across her wings. The moth has a wingspread of about 1 in. The female deposits her eggs on the lower surfaces of the plant. Usually within a week the eggs hatch, and the developing larvae feed on the host plant, finally boring into all parts. Often so many larvae are present that the plant collapses. The insect spends the winter as a full-grown worm in the plant on which it feeds. The following spring, a cocoon is formed and the adult moth emerges early in the summer to complete the cycle. As the moths may fly for considerable distance, the area of infestation tends to spread rather rapidly into insect-free areas.

Controlling the Corn Borer.—Complete sanitation to destroy all parts of plants that may harbor the borer seems to be essential. Cutting the corn plants close to the surface with the ensiling of the fodder has proved effective. Special attachments have been devised to make it possible to cut the plants near the surface. The shredding of fodder does an effective job of destroying the worms within the stalks. It is necessary that all refuse be destroyed to prevent the insect from hibernating in the material left in the field. A clean job of plowing with thorough disking will destroy many larvae. Since soybeans, the clovers, and alfalfa are not generally attacked by the corn borer, their inclusion in the rotation has aided in control. Natural parasites have been introduced by Federal and state authorities and doubtless have aided in checking the advance of the borer.

Considerable work has been done by the plant breeder in his efforts to control the corn borer. Patch *et al.*[1] in reporting on breeding corn for resistance to the corn borer stated, "The cumulative effort of an undetermined number of multiple factors in inbred lines in producing borer resistance in hybrids is clearly indicated."

CORN EARWORM

The corn earworm is one of the most serious pests of the corn plant. Not only are yields reduced, but the quality of the crop may be lowered. This is particularly true in the case of sweet corn. The burrowing of the worms into the tip of the ear provides an opportunity for water to gain entrance to the husk and may result in added spoilage and secondary development of molds and diseases on the exposed grain.

Life Cycle of the Earworm.—*Heliothis armigera* Hbn. is probably

[1] Patch, L. H., J. R. Holbert, and R. T. Everly, Strains of Field Corn Resistant to the Survival of the European Corn Borer, *U.S. Dept. Agr. Tech. Bull.* 823, 1942.

known to every gardener who has raised sweet corn. The moth survives the winters only in the Southern states, so that attacks in the Northern states are the result of the northern migration of the moth. The moths, with a wingspread of about $1\frac{1}{2}$ in., vary in color but usually have front wings of light brown with gray wavy lines and darkened regions near the wing tips. The back wings are white with irregular dark spots. The moth, which appears early in the summer, deposits its eggs on young corn plants. Later in the season the eggs are deposited on the developing corn silks where they hatch and the larvae burrow their way, feeding on the silks and the corn kernels. On attaining its maturity, the larva leaves the ear, falls to the ground, and burrows into the soil, where it pupates, passes the winter, and emerges as an adult moth with the coming of warm weather.

Controlling the Earworm.—A thorough job of early plowing may aid in destroying many of the insects while in hibernation. In small areas, the worm is checked through the application of poisonous dusts or sprays on the silks. This is not practical on a field scale and is not an important means of control. Blanchard *et al.*[1] have reported on the breeding of lines of corn that are resistant to the corn earworm.

THE CHINCH BUG

This is one of the worst insects of grain crops. During the dry year of 1934, the losses in the corn belt amounted to millions of dollars. Every year some damage results, but the attacks are especially serious in certain years. A field of corn that has been seriously attacked by chinch bugs may look much as though a fire had passed through, searing the plants and causing them to wilt and die prematurely.

Life Cycle of the Chinch Bug.—*Blissus leucopterus* (Say.) in the adult stage is a small black bug about $\frac{1}{5}$ in. in length. The white wings are marked with black triangles which aid greatly in recognizing the insect. When crushed, the insect gives off a foul odor which is so characteristic that it is another means of identification.

Adult insects hibernate in weeds or grasses near the fields. In the spring the adults emerge and lay their eggs on the small grains, particularly wheat, and grasses. The first generation lives on the grain crops, sucking the juices from the plant. As the wheat matures the insects are forced to search for succulent vegetation, and they migrate to near-by corn or sorghum fields where they complete their life cycle. Often a second generation develops on the corn and, if conditions are favorable, may be much more serious than the first generation. In the South it is

[1] Blanchard, Ralph A., John H. Bigger, and Ralph O. Snelling, Resistance of Corn Strains to the Corn Earworm, *J. Am. Soc. Agron.*, **33** : 344–350, 1941.

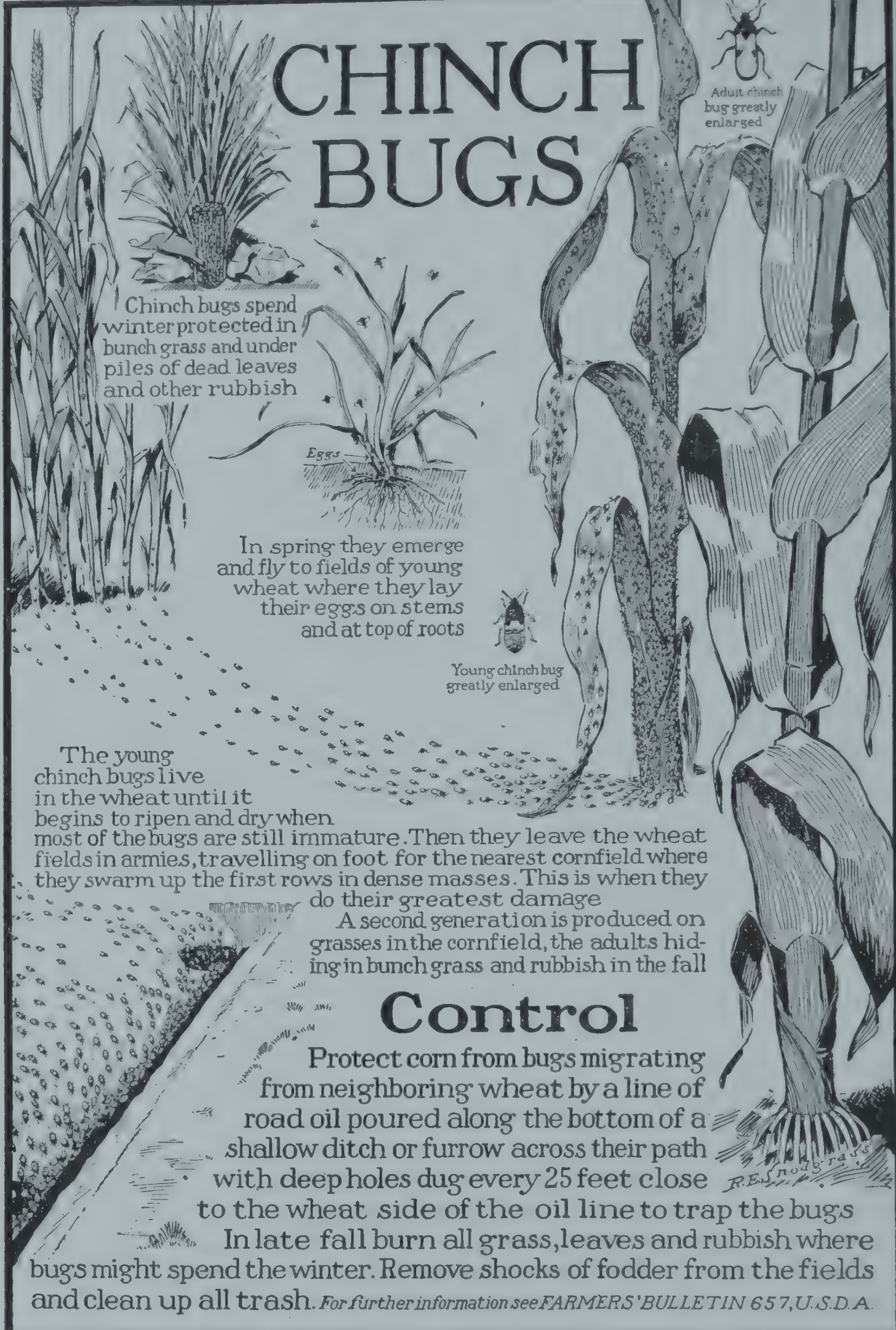


FIG. 48.—The chinch bug. *(Courtesy of the Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture.)*

not unusual for a third generation to develop. In dry years when the insects are favored, they may develop in enormous numbers so that several hundred may be found on a single corn plant. With such heavy infestation it requires but little time to destroy the crop.

Controlling the Chinch Bug.—Since the chinch bug lives only on members of the grass family, crop rotation is a certain means of control. This, however, upsets plans and is not always practical. As the bugs migrate from the small grain field to the cornfield, it is well to avoid planting these crops adjacent to each other.

Thorough destruction of all weeds and plant refuse adjacent to fields will destroy many of the hibernating adults. This has been of value in the more humid areas. Thoroughly plowing under all crop residues is advisable.

When the insects have appeared in the grain field it is possible to trap them as they migrate to new pastures. As they travel on foot at this time, it is possible to construct barriers around the field. A most effective barrier is to spread a narrow line of crude creosote at one edge of the field alongside a ridge or plowed furrow. The odor of the creosote will repel the insects, and they may be caused to fall into postholes dug in the furrow on the small-grain side of the barrier. In severe attacks, at the time of migration the insects may fall into these holes so rapidly as to resemble a stream of water. From time to time a small amount of kerosene may be poured into the holes to destroy the trapped bugs. The use of creosoted strips of paper placed along the edge of the field to project above the surface has proved effective and is believed to be more economical than the use of the creosoted line spread on the surface of the soil.

A program of breeding for resistance to the chinch bug is being carried out by several workers. Jones,[1] studying the reaction of 168 strains of wheat, found that 20 per cent suffered little or no injury, while 80 per cent suffered moderate to severe injury. Dahms and Martin[2] reported that, in a study of 11 sorghum hybrids in the F_1 generation and their parents, it was indicated that in most of the crosses resistance was dominant to susceptibility.

HESSIAN FLY

To the uninitiated the Hessian fly is not readily evident in its attacks on the crop. The plants in the fall may appear stunted, with an un-

[1] JONES, E. T., Differential Resistance to Chinch Bug Attack in Certain Strains of Wheat, *Trans. Kans. Acad. Sci.*, **40**: 135–142, 1937.

[2] DAHMS, R. G., and J. H. MARTIN, Resistance of F_1 Sorghum Hybrids to the Chinch Bug, *J. Am. Soc. Agron.*, **32**: 141–147, 1940.

thrifty color. In severe infestations many of the plants die during the winter, and with the coming of active growth it is not uncommon for a great majority of the plants to break over with heavy losses.

Life Cycle of the Hessian Fly.—*Phytophaga destructor* (Say.) usually attacks wheat, although it may occur on barley and rye. It receives its name from its introduction by Hessian troops who were quartered in America during the Revolutionary War. The insect hibernates in the fly or maggot stage, usually in the puparium case in the so-called *flaxseed stage*, so named because it resembles a flaxseed. The puparium is between the leaf sheath and the stem of the plant. In the spring the adult emerges as a small two-winged fly of a dirty-black color and very small in size. The flies deposit their eggs on the plants where they hatch within 3 to 10 days. The larvae feed on the plants, sucking the juices and causing their destruction in severe attacks. Two generations may develop under favorable conditions. The adults lay their eggs on the young wheat plants, the larvae passes into the flaxseed stage, and the cycle is completed.

Controlling the Hessian Fly.—The principal means of control lies in taking advantage of the life cycle of the fly. If the crop is planted late enough, it will not emerge until after the flies have layed their eggs and died. For each section the state entomologists predict the date of egg laying; then they set what is known as the *fly-free date*. Farmers know that wheat planted after the fly-free date will not be attacked by the Hessian fly. In the more northern states the Hessian fly is not a problem in average seasons. The destruction of volunteer wheat plants is advisable, as they may provide a source of spring infestation. A thorough job of plowing under the stubble of infested fields will check most of the insects that may be present.

Reitz *et al.*[1] report that hybrids with Marquillo as one of the parents were sufficiently resistant and tolerant to the Hessian fly to be of high economic importance.

Painter *et al.*[2] were able to develop several winter hybrids from Marquillo spring wheat crossed with winter wheat that showed different combinations of resistance to the Hessian fly and tolerance to the joint worm. They state that these hybrids are the first winter wheats to

[1] Reitz, L. P., R. T. Jones, C. O. Johnston, and R. H. Painter, Agronomic Tests of New Resistant Varieties and Hybrids of Hard Red Winter Wheat in the Presence of Stem Rust and Hessian Fly, *J. Am. Soc. Agron.*, **35**: 216–229, 1943.

[2] Painter, R. H., E. T. Jones, C. O. Johnston, and J. H. Parker, Transference of Hessian Fly Resistance and Other Characteristics of Marquillo Spring Wheat to Winter Wheat, *Kans. Agr. Expt. Sta. Tech. Bull.* 49, 1940.

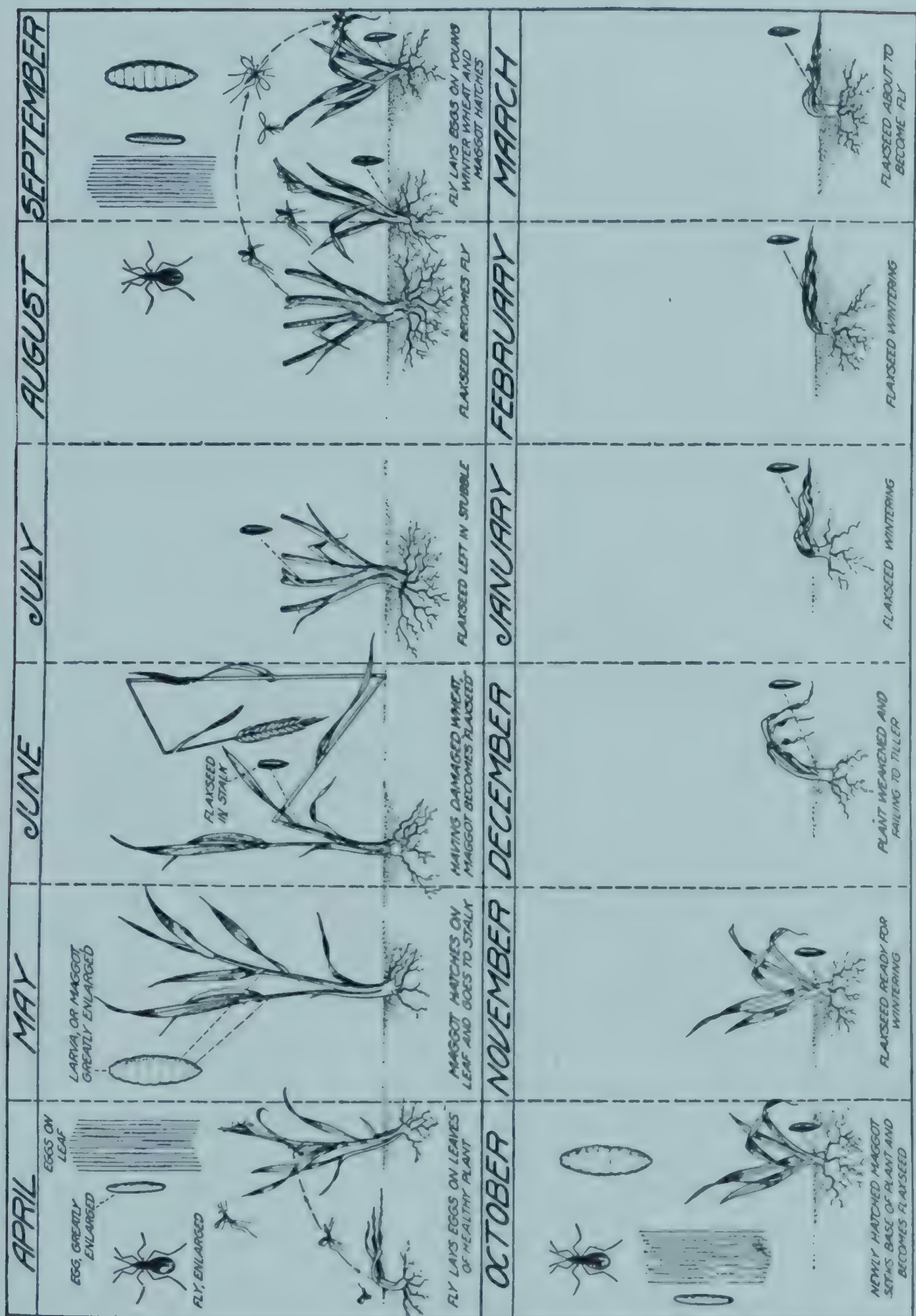


FIG. 49.—Life cycle of the Hessian fly. (*Courtesy of the Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture.*)

show marked resistance to the Hessian fly in experimental tests in both the hard and soft wheat belts.

THE GREEN BUG

The green bug or aphid frequently causes great losses to small grains, especially wheat in the hard red winter areas of the Southwest. When conditions favor its development, the pest may destroy or greatly injure the plants as it sucks their juices during late winter and early spring.

Life Cycle of the Green Bug.—*Toxoptera graminum* Rondani passes the winter in the nymph and adult stages, becoming active during the warmer periods. In the cooler sections the insect lays its eggs on the leaves of the host plants, and thus it passes the winter. In the late winter or early spring the eggs hatch and the light green wingless females develop. These females are able to give birth to living young, which may or may not possess wings. Many generations result if conditions are favorable, and the pests may become so numerous that the crop may be destroyed.

Controlling the Green Bug.—Man is rather at the mercy of the environment as this pest develops rapidly during mild winters and cool late springs. If the temperatures are higher in the spring a parasitic wasp develops, and this aids greatly in checking the rapid spread of the green bug. It is believed that the destruction of volunteer grains in the field following harvest aids in control. Little progress has been made in developing resistant varieties, although Wadley[1] reported that Mindum durum and Vernal emmer were not favorable hosts to the green bug.

STORAGE INSECTS

Those pests which infest grains after they have been harvested and stored cause tremendous losses each year. During the period when the Federal government was storing grain, the problems of storage insects became greater then ever before. The problems are especially great when it is necessary to hold grain for more than one season in the North. In the warmer areas of the country, the storage insects are especially troublesome as there is no check such as the low temperature of the North. The seed dealer who must hold the grain in storage is very likely to encounter serious problems, and the same is true of the miller in the storage of both the grain and the processed products.

Grain Weevils.—Storage insects are frequently found where grain

[1] WADLEY, F. M., Ecology of *Toxoptera graminum*, Especially as to Factors Affecting Importance in the Northern United States, *Ann. Entomol. Soc. Am.*, **24**: 325–395, 1931.

or its products are held for long periods. The granary weevil [*Sitophilus granarius* (L.)] and the rice weevil [*S. oryzae* (L.)] are the two species of greatest importance. The small shiny brown beetle, about $\frac{1}{16}$ in. in length, is characterized by its long snout, or proboscis.

The female eats small holes in the grain and deposits her eggs. Here the larvae, small white grubs, hatch and feed on the grain, destroying all but the seed coat. The larvae pupate and emerge as adults within a period of 7 to 8 weeks, with several generations developing within a year. The weevils live on wheat, corn, oats, barley, or rye but are unable to develop in milled products such as flour. The rice weevil resembles the granary weevil but is more active in that it can fly, while the granary weevil does not use its wings. Both insects develop slowly at temperatures below 70°F. or in grain with a moisture content below 13 per cent.

FIG. 50.—The granary weevil. (*Courtesy of the Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture.*)

Angoumois Grain Moth.—*Sitotroga cerealella* (Oliv.) according to Shepard[1] is second only to the grain weevils in destructiveness, especially to corn, both in the ear and shelled.

The adult is a small moth with a wingspread of about $\frac{1}{2}$ in. and a buff or grayish-brown color with a satin luster. The wings are narrow and pointed with wide fringes. The adult lays its eggs on or near the grain, and the newly hatched larvae bore into the kernel where they feed while developing. Here they pupate and emerge in about 3 weeks as adults. The entire life cycle may be completed within 5 weeks, and the insect passes through generation after generation under favorable conditions until all grain is destroyed. In warmer areas, as in the South, the adult lays its eggs on immature grain in the field and much damage may occur before harvest.

Saw-toothed Grain Beetle.—*Oryzaephilus surinamensis* (L.) is often found in stored grain or food and feed products. Frequently, it gains entrance into packaged foods and causes great losses. It is unable to

[1] SHEPARD, HAROLD H., Insects Infesting Stored Grain and Seeds, *Minn. Agr. Expt. Bull.* 340, 1940.

penetrate sound grain and feeds only upon broken or injured seeds, often following the attack of other insects. The adult is a small dark-brown beetle about $\frac{1}{10}$ in. in length and derives its name from the toothlike projections on the sides of the thorax. The adult female deposits her eggs on or near food, where they hatch within a week or less. The brown-headed white larvae crawl as they feed, and in 3 weeks or more they pupate. In about 10 days the adult beetle emerges, completing the life cycle in 3 to 10 weeks, depending upon environmental conditions.

Mediterranean Flour Moth.—*Ephestia kuehniella* (Zeller) is probably the most serious pest of the miller. Its presence is indicated by the webbings that develop in elevator and mill passageways.

Although flour is the favorite food of this insect, it may attack wheat grain and other food products. The adult moth is pale gray in color and about $\frac{3}{8}$ in. in length. The adult female deposits her eggs in flour or other food, in cracks, or in the cloth of the bolters. Within 3 to 6 days the eggs hatch into small pink to white caterpillars which spin webs in which they live and feed. The larvae pupate and complete their life cycle within 9 to 10 weeks.

Controlling Storage Insects.—For the most part the general methods of control are similar for the various storage insects.

Sanitation to prevent infestations of new grain is a cardinal principle. It is especially advisable to clean out old grain bins before adding new grain. It is common for farmers to leave a small quantity of grain in the corners and cracks of bins and to deposit the new grain without any effort of cleaning. It is important to clean the upper surface of timbers and any space where insects may hide.

Where the winter temperatures are low the storage insects are held in check since nearly all are inactive at temperatures of 43°F. and below. In the northern states, such low temperatures are found during several months of the year and operate as an effective check to the insects.

Fumigation.—The use of chemicals to destroy insect pests that have gained access to the stored grain is a necessary and effective means of control under many conditions.

Several types of fumigants have proved to be of value in insect destruction. All are effective in that they provide temporary conditions under which the insect dies but the grain is uninjured.

Ethylene chloride has proved to be effective and is relatively cheap. It has a low fire hazard and is not especially dangerous to humans. Mixing 3 parts of it to 1 of carbon tetrachloride removes the fire hazard. As it evaporates slowly it requires some 24 hr. to effect a treatment.

The required dosage is 14 lb. of the 3 to 1 mixture to each 1,000 cu. ft. of grain at ordinary temperatures.

Propylene chloride may be substituted for ethylene chloride and used in the same manner. It is slower to vaporize but otherwise should prove equal to the ethylene chloride.

Carbon tetrachloride is a noninflammable liquid that evaporates at about the same rate as ethylene chloride. However, it is not so effective as some of the other chemicals. The usual dosage is 20 to 30 lb. to each 1,000 cu. ft. The warmer the weather, the less the fumigant required.

Carbon disulfide is more effective than carbon tetrachloride but has the disadvantage of being highly explosive and very inflammable. In general, because of the danger from its use, it is not recommended as a fumigant.

Chloropicrin, or tear gas, is a very toxic noninflammable fumigant that is injurious to man in small quantities. It is sprayed into the area to be treated or diluted with equal parts of carbon tetrachloride to improve its evaporating powers. The usual dosage is 2 lbs. of chloropicrin to 1,000 cu. ft. of space. In no case should it be used by an inexperienced operator, and it is advisable to wear a mask to avoid injury.

Hydrocyanic acid gas is one of the most satisfactory fumigants, especially where it is necessary to do a large-scale job as in a grain elevator. The extremely poisonous properties of the gas make it imperative that it be used with great care by one who is experienced in handling the material. Usually, granular calcium cyanide is mixed with sulfuric acid to form the powerful hydrocyanic gas. The gas is very volatile and spreads upward rapidly and may penetrate adjoining rooms. It diffuses downward very slowly and is not effective in the treatment of large masses of grain. The common practice in elevators is to feed the gas into a stream of grain as it is moved from one bin to another and thus make it possible for the gas to come into contact with all insects that may be carried on or in the grain.

DDT

A new insecticide, dichloro-diphenyl-trichloroethane, commonly known as DDT, has been successfully used by the American armed forces since 1942. This chemical appears to have a real place in the control of insects both in the field and under storage conditions. It has proved particularly effective in the destruction of many types of insects. A single treatment may prove effective over a long period of time, thus obviating to a large degree the necessity for further retreatments.

Review Questions

1. What injurious insects occur in your community?
2. What grain crops suffer from insect damage?
3. How is a severe infestation of grasshoppers related to rainfall?
4. Give the plans for making poison bait.
5. Give an example of breeding for insect resistance.
6. Outline the life cycle of the white grub.
7. What crops appear resistant to the white grub?
8. How can one reduce the damage from corn rootworms?
9. How is the wireworm controlled?
10. What conditions favor the development of cutworms?
11. Give the life cycle of the European corn borer.
12. Why is sanitation so important in the control of the corn borer?
13. How can one control the corn earworm?
14. Outline methods of checking the chinch bug.
15. Why does delayed planting of winter wheat aid in Hessian-fly control?
16. Describe the damage done by green bugs.
17. Name the important storage insects.
18. How can one control storage insects?
19. Why is carbon disulfide dangerous to use?
20. What are the possibilities of DDT?

References

ARBUTHNOT, K. D.: Strains of the European Corn Borer in the United States, *U.S. Dept. Agr. Tech. Bull.* 869, 1944.

BATCHELDER, C. H., D. D. QUESTEL, and N. TURNER: European Corn Borer Investigations, *Conn. Agr. Expt. Sta. (New Haven) Bull.* 395, 1937.

CALDWELL, RALPH M., W. B. CARTWRIGHT, and LEROY E. COMPTON: Inheritance of Hessian Fly Resistance Derived from W38 and Durum P.I. 94587, *J. Am. Soc. Agron.*, **38**: 398–409, 1946.

CARTWRIGHT, W. B., and R. S. SHANDS: Wheat Varieties Resistant to the Hessian Fly and Their Reactions to Stem and Leaf Rusts, *U.S. Dept. Agr. Tech. Bull.* 877, 1944.

Corn Borer Numbers Increase, *Ill. Agr. Ext. Circ.* 576, 1944.

COTTON, R. T., J. C. FRANKENFIELD, and G. R. DEAN: Controlling Insects in Flour Mills, *U.S. Dept. Agr. Circ.* 720, 1945.

FREAR, D. E. H.: "Chemistry of Insecticides and Fungicides," D. Van Nostrand Company, Inc., New York, 1942.

GRANOVSKY, A. A.: How to Control White Grubs, *Minn. Agr. Ext. Folder* 112, 1942.

HORTON, J. R., E. T. JONES, H. H. WALKDEN, and G. A. DEAN: Wheat-seeding Dates and the Hessian Fly in Kansas, *Kan. Agr. Expt. Sta. Tech. Bull.* 59, 1945.

METCALF, C. L., and W. P. FLINT: "Destructive and Useful Insects," 2d ed., McGraw-Hill Book Company, Inc., New York, 1939.

MILLS, H. B., J. A. CALLENBACH, and J. F. REINHARDT: Montana Insect Pests, 1943 and 1944, *Mont. Agr. Expt. Sta. Bull.* 425, 1945.

MUNRO, J. A., and H. S. TELFORD: Grasshopper Control Aided by Tillage Methods, *N. D. Agr. Expt. Sta. Bull.* 309, 1942.

PACKARD, C. M., and W. B. CARTWRIGHT: The Hessian Fly in Indiana, *Purdue Univ. Agr. Expt. Sta. Bull.* 440, 1939.

PAINTER, R. H., E. T. JONES, C. O. JOHNSTON, and J. H. PARKER: Transference of Hessian Fly Resistance and Other Characteristics of Marquillo Spring Wheat to Winter Wheat, *Kans. Agr. Expt. Sta. Tech. Bull.* 49, 1940.

PATCH, L. H., and RAY T. EVERLY: Resistance of Dent Corn Inbred Lines to Survival of First-generation European Corn Borer Larvae, *U.S. Dept. Agr. Tech. Bull.* 893, 1945.

SPAWN, GERALD B.: Tillage Methods in Grasshopper Control, *S. D. Agr. Expt. Sta. Bull.* 379, 1945.

TAPP, J. W., G. W. COLLIER, and C. R. ARNOLD: Farm Practices under Corn Borer Conditions, *U.S. Dept. Agr. Farmers' Bull.* 1562, 1928.

WALKDEN, H. H., J. R. HORTON, and F. M. WADLEY: Hessian Fly Control in Nebraska by Late Sowing of Winter Wheat, *Neb. Agr. Expt. Sta. Bull.* 360, 1944.

WILBUR, D. A., H. R. BRYSON, and R. H. PAINTER: Southwestern Corn Borer in Kansas, *Kans. Agr. Expt. Sta. Bull.* 317, 1943.

CHAPTER IX

WHEAT AND RYE

WHEAT

Without a doubt more people in the United States look upon wheat products as an essential part of their diet than on any other crop plant. To the Occidental part of the world, wheat serves much the same as rice in the Orient. Few Americans eat a meal without partaking of foods processed from wheat. Since earliest historical times the wheat plant has occupied a place of first importance as a food plant. On the markets of the world the price of wheat tends to dominate the prices of all other grains, and in general its rise and fall are reflected by that of the other

TABLE 29.—IMPORTANT SPECIES OF TRITICUM

Pairs of chromosomes		
7	14	21
T. monococcum L. *T. aegilopoides* Bal.	*T. durum* Desf. *T. dicoccum* Schubl. *T. turgidum* L. *T. polonicum* L. *T. timopheevi* Zhuk.	*T. vulgare* Vill. *T. compactum* Host. *T. spelta* L.

grains. The importance of the crop in the world makes its study of especial interest to the student of agriculture.

CLASSIFICATION OF WHEAT

There are several bases that may be used to classify wheat, but the most important are the groupings based on botanical characteristics and the more or less artificial schemes used in marketing. Each system has its value and place and is important in an understanding of wheat production.

Botanical Classification.—Wheat belongs to the grass family *Gramineae* (Poaceae) and the genus *Triticum*. Although as many as 18 species

of wheat have been described and recognized by Percival[1] and others, only a few are of importance in agriculture.

In the early days of taxonomy, classification was based almost entirely upon morphological characteristics. Recently more and more use is made of the chromosomal make-up of species as guides to their proper arrangement within the genus, and today the major groups of wheat are classified on the basis of chromosomal number.

T. aegilopoides is more grasslike than *T. monococcum* with more forms or varieties, some of which have somewhat longer kernels.

T. durum, sometimes called macaroni wheat, but more correctly referred to as *durum wheat*, develops amber or red kernels whose hardness makes them well suited to the manufacture of macaroni and related products.

T. dicoccum is a tight glume wheat like einkorn, grown to a limited extent as a feed wheat. The common name *emmer* is not widely used, as most farmers erroneously refer to this wheat as *spelt* or *speltz*. Because of certain disease-resistant qualities, this species has been used successfully in the improvement of hard red spring wheat varieties.

T. turgidum, known as *Poulard*, sometimes called *cone* or *branched wheat*, is characterized by the tendency to produce a branched wedge-shaped spike. As an economic crop it is of little importance except in England.

T. polonicum, or Polish wheat, has an extremely long, flinty kernel enclosed within very long thin glumes. This species is of little importance.

T. timopheevi, a fairly recent species, possesses certain disease-resistant qualities and is being used in crosses with standard varieties.

T. vulgare (aestivum), or common wheat, includes many varieties of both winter or spring habit and includes most of the varieties of wheat used for breadmaking. The kernels are usually red or white.

T. compactum, or club wheat, is characterized by the club-shaped spikes resulting from multiflorate spikelets of especial importance in the Pacific northwest. Kernels are white or red in different varieties.

T. spelta, or speltz, retains its glumes like emmer, with which it is commonly confused. It is of no economic importance in America.

Hayes and Immer[2] have summarized the modern viewpoint of classi-

[1] Percival, John, "The Wheat Plant," Gerald Duckworth & Co., Ltd., London, 1921.

[2] Hayes, H. K., and F. R. Immer, "Methods of Plant Breeding," McGraw-Hill Book Company, Inc., New York, 1942.

fying wheat species on the basis of genoms (sets of seven chromosomes) as follows:

Einkorn Series
($n = 7$)
AA
Triticum aegilopoides
Triticum monococcum

Timopheevi Series
($n = 14$)
AAGG
Triticum timopheevi

Aegilops Series
($n = 14$)
CCDD
Aegilops cylindrica

Emmer Series
($n = 14$)
AABB
Triticum dicoccoides
Triticum dicoccum
Triticum durum
Triticum turgidum
Triticum pyramidale
Triticum polonicum
Triticum persicum

Spelt Series
($n = 21$)
AABBCC
Triticum spelta
Triticum vulgare
Triticum compactum

Fig. 51.—The less common species of wheat. Left to right, spikes of Polish, einkorn, spelt, emmer, durum, and poulard. *(Courtesy of J. A. Clark, U.S. Department of Agriculture.*

Of the genoms listed above as A, B, C, D, and G, each contains a set of seven chromosomes. Each represents the reduced or haploid number. The basic number seven is in the germ cells, which is half that in the body or somatic cells. This doubling produces the diploid number of 14, 28, and 42 chromosomes for the different wheat species listed in Table 29.

It is recognized that in order to gain a thorough understanding of the species as classified on a genetic basis an adequate knowledge of botany and genetics is necessary. The interested student should refer to Hayes and Immer, "Methods of Plant Breeding," for a detailed discussion of the breeding relationships of the different species.

Wheat as a World Crop

Although many peoples of the world eat rice as their principal cereal, wheat is very widely grown and eaten by millions of people. Normally, it is grown on nearly 400 million acres each year in 50 different countries. The leading countries and their average production for the years 1930–1934, according to figures prepared by workers in the United States Department of Agriculture,[1] are given in Table 30.

Table 30.—Principal Wheat-producing Countries of the World (more than 50,000,000 bu.) (1941–1944 average except as indicated)

Country	Bushels	Country	Bushels
North America:		Union of Soviet Socialist Republics	860,448,000*
United States	959,243,000		
Canada	397,876,000	Africa	133,250,000
Total including Mexico	1,373,500,000		
		Asia:	
Europe:		China	715,536,000†
Italy	245,103,000	India	370,660,000†
France	229,646,000*	Turkey	135,690,000†
Germany	170,212,000*		
United Kingdom	104,493,000	South America:	
Rumania	103,447,000*	Argentina	218,367,250
Spain	97,719,000		
Yugoslavia	79,494,000*	Australia and New Zealand	129,340,500
Hungary	76,506,000*		
Poland	74,267,000*		
Czechoslovakia	53,697,000*		
Bulgaria	52,864,000*	Estimated world total	3,786,000,000‡

* 1930–1934 average.
† 1935–1939 average.
‡ 41 countries, but does not include Soviet Russia and China.

Of the nearly 4 billion bushels of wheat produced annually in the world from 1941 to 1944, more than one-fourth of the total was grown in

[1] United States Department of Agriculture, *Agricultural Statistics*, 1943.

North America. It is evident that more wheat was produced in America than could be consumed by her own people. Prior to the advent of the Second World War, large surpluses accumulated and the Federal government stored great quantities of wheat and other grains throughout the producing areas. On an average during the 10-year period previous to the Second World War, the United States exported approximately 59 million bushels of wheat (including flour) each year. Compared with our average total production, it is apparent that the amount of export trade was relatively small in relation to the total volume of wheat produced. The use of land tends to demand the growing of those crops which are most profitable. If the export trade cannot be increased, wheat acreages are likely to be reduced unless price-bolstering plans are used. The shift to other crops is not an easy adjustment, since many of the best wheat-producing areas are better suited to wheat-growing than to any other crop. No other farm enterprise has proved as generally profitable as the growing of wheat in those sections where rainfall is a limiting factor for most other crops yet proves adequate for the production of wheat of very high quality.

A survey of those countries which are competitors of the United States in wheat growing shows that in general they possess areas of similar soil and climatic conditions. Wheat is well adapted and tends to have first choice for the use of the land. Examples of the similar conditions are the great chernozem areas of Russia and the fertile pampas of Argentina. In North Dakota and the prairies of Russia and Argentina are found fertile, dark soils rich in nitrogen, rather hot, cloudless summers, and a rainfall which although low in total amount is generally so distributed that it favors the growing of cereal grains.

Waldron *et al.*[1] have shown the significant relationships between protein and quality in spring wheat and the temperature and rainfall. High temperatures just before the wheat plants headed were associated with greater loaf volume and increased percentage of protein.

Wheat in the United States

Wheat is very widely grown in the United States, but certain areas stand out as of major importance as producing sections. The crop ranks third to corn and oats among the grains in total production but is second only to corn in farm value. For an average of 10 years (1930–1939) the farm value of the wheat produced in the United States was $514,671,000.

[1] Waldron, L. R., R. H. Harris, T. E. Stoa, and L. D. Sibbitt, Protein and Quality in Hard Red Spring Wheat with Respect to Temperature and Rainfall, *N. D. Agr. Expt. Sta. Bull.* 311, 1942.

In the bumper crop year of 1945 the total production was the greatest in history, exceeding one billion bushels and representing a farm value of more than one billion dollars.

In Chap. III the leading wheat-producing states were considered by type of wheat grown. Reference should be made to this chapter to orient properly the leading wheat-growing states and their relative importance in America.

Uses of Wheat

TABLE 31.—AVERAGE ANNUAL PRODUCTION AND FARM DISPOSITION OF WHEAT, IN BUSHELS, IN THE UNITED STATES*
(1941–1942 average)

Total production	Used for seed	Fed to livestock	Ground at mill or exchanged for flour	Sold
962,227,000	63,066,000	100,109,000	12,736,000	786,316,000

* United States Department of Agriculture, *Agricultural Statistics*, 1943.

It is evident from Table 31 that the greatest part of the wheat produced in the United States is marketed as grain. In the early history of the United States, when the country was sparsely settled, a much greater percentage of wheat was milled on the farm or was taken to a local mill where it was exchanged for flour. In those times it was common to transport sufficient wheat to the mill to obtain the flour required for a year. Today this practice is not common. The great increase in mills and bakeries and better means of transportation have led to a decrease in home baking. In many farm homes baker's bread is as common as in the urban areas, and this has resulted in less use of the small local mills, and many of these have been abandoned. The amount of wheat used for seed is fairly stable, varying but little from year to year as acreages planted may increase or decrease.

Most of the wheat marketed is used to manufacture flour from which bread, cakes, and pastries are made. The soft white wheats are used extensively for crackers, pastries, and cookies. The durum wheats are processed into semolina from which macaroni and related products are made.

Wheat is an excellent feed for livestock and is used rather generally in those areas where the crop is of limited importance and the grain is largely used on the farm. For example, in New Jersey and Arkansas the greater part of the total wheat crop is fed on the farm to livestock.

This is of little significance in the total wheat picture since neither state is important in wheat production. In the important wheat states of North Dakota and Kansas only about 3 to 4 per cent of the wheat produced is fed to livestock.

From Table 32 it is evident that wheat is rich in protein, the most expensive of the feed materials. Also, of the grains tested it contains the highest percentage of the energy-rich carbohydrates, whereas the percentage of fiber, the nondigestible material of grain, is low. Wheat bran, which is a by-product of the milling industry, is richer in protein than the wheat grain, although it does contain a higher percentage of fiber. It is greatly prized by livestock feeders and, because of its high protein content, is especially valuable for young animals and as an important part of the ration in bringing fattening animals to a high finish.

Table 32.—Average Composition of Wheat and Other Grains[1]

Grain	Protein, per cent	Nitrogen-free carbohydrates, per cent	Fat, per cent	Fiber, per cent	Nutritive ratio, 1:
Wheat (recent analyses)	13.1	70.0	1.7	3.0	6.4
Wheat bran (all analyses)	15.8	54.3	5.0	9.5	24.4
Oats*	12.0	60.2	4.7	10.6	6.6
Barley, common*	11.8	68.0	2.0	5.7	7.5
Corn, dent No. 2	9.4	68.4	3.9	2.2	10.3

* Not including Pacific Coast states.

Wheat straw is used for bedding on farms, and some is manufactured into paper. Much of the straw in the leading wheat-producing areas is wasted, usually being burned following threshing.

In the winter wheat districts the growing wheat plants provide valuable pasturage both in the fall and spring. Usually the fields are not grazed intensively, as this is likely to result in decreased grain production. Care must be exercised to avoid grazing when the soil is wet, or severe damage is certain to result from the trampling of the livestock.

Wheat harvested when immature makes a good grade of hay. For the best hay it is important that the crop be cut when the grain is in the milk stage. The forage is both nutritious and palatable and is often used for emergency feed in years of drought in the humid areas. In

[1] By permission, F. B. Morrison, "Feeds and Feeding," 20th ed., The Morrison Publishing Company, Ithaca, N. Y., 1940.

some sections, as in the Pacific Coast states, wheat and other cereals are frequently grown for hay.

MARKET CLASSIFICATION OF WHEAT

The market classification of the wheats is based upon the uses made of the different types and does not necessarily bear any relationship to their botanical groupings. For many years there was no definite uni-

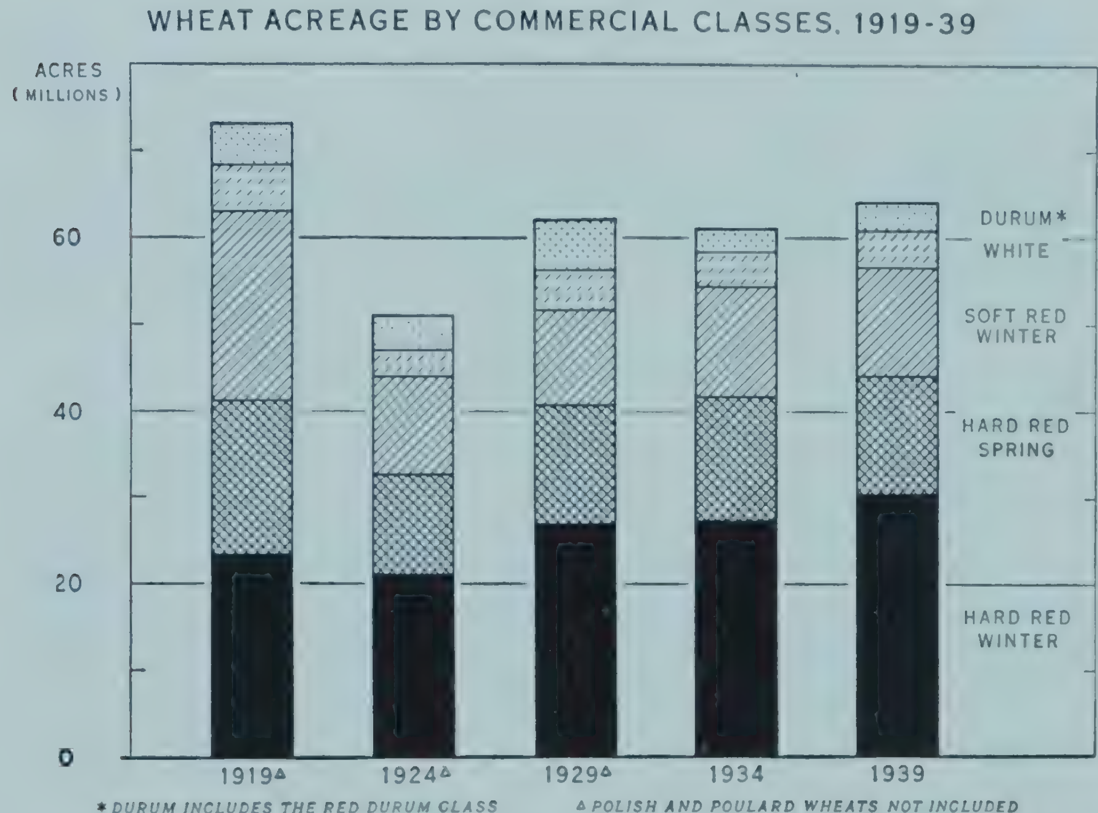


FIG. 52.—Wheat acreage by commercial classes, 1919–1939. (*Courtesy of the Bureau of Agricultural Economics, United States Department of Agriculture.*)

versal system of classifying wheats, and much confusion arose when grain was shipped from one section of the country to another.

The Chicago Board of Trade set up grades for wheat prior to the War between the States. The bases for the grades were not well established and included such ambiguous groupings as sound, dry, plump, and reasonably clean, which naturally led to much misunderstanding between the buyer and the seller. Other states followed the lead of Illinois and established grading systems, which varied greatly in their scope and interpretation. It was not until Aug. 11, 1916, that the Federal government, realizing the handicap under which the grain markets were oper-

ated, passed the United States Grain Standards Acts. Since the passage of the original act several amendments have been made, as experience dictated the changes. Based on the present standards, wheat is grouped in seven classes:[1]

Hard red spring wheat
Hard red winter wheat
Soft red winter wheat
Durum wheat
Red durum wheat
White wheat
Mixed wheat

FIG. 53.—Inspector sampling grain in a box car of wheat. The grain obtained from all parts of the car with the trier or probe is dumped on a canvas. A representative sample is taken to the laboratory for grading. (*Courtesy of the United States Department of Agriculture.*)

Under the provisions of the grain standards, wheat is defined as "any grain which before the removal of dockage consists of 50 per cent or more of wheat and not more than 10 per cent of other grains for which standards have been established under the provisions of the United States Grain Standards Act. . . ."

The Federal standards have made it possible to ship grain from one state to another with complete confidence on the part of both the buyer and the seller. Also they make possible the dealing in futures on the

[1] Handbook of Official Grain Standards of the United States, *U.S. Dept. Agr., U.S. Grain Standards Act, Form* 90, revised 1941.

grain market with its many advantages. The actual grading of the grain in the various terminal markets is done by state inspectors, who are required to pass Federal examinations to demonstrate their qualifications to grade grain properly. At all times these inspectors are under the supervision of the Federal Grain Supervision Office, which has offices in the leading grain markets of the country. The Federal offices supervise the work, interpret the rules, do educational work, and serve

FIG. 54.—A Federal grain supervision office. (*Courtesy of the U.S. Department of Agriculture.*)

as a board of appeals when either the buyer or the seller is dissatisfied with the grade placed on the grain by the state inspector.

Hard Red Spring Wheat.—Essentially this is a bread wheat, and most of the varieties are used for the manufacture of high-quality flour. In general, when well matured the kernels are hard and flinty, rich in protein, and possess the qualities that permit the baking of large loaves of bread from a given quantity of flour. The gluten is of such character that it is elastic and the loaf may increase in volume without a breakage of the crust, which when baked properly has a smooth, even surface.

Grading.—On the basis of the percentage of dark, hard, and vitreous kernels, hard red spring wheat may be graded into three subclasses:

Dark northern spring	75 or more per cent dark, hard, and vitreous kernels
Northern spring	More than 25 and less than 75 per cent dark, hard, and vitreous kernels
Red spring	25 or less per cent dark, hard, and vitreous kernels

If the lot of wheat contains more than 10 per cent of the undesirable variety Humpback, it is graded red spring regardless of its texture. However, relatively little Humpback is grown in this country.

Other factors considered in the final determination of the numerical grade are damaged grain, the presence of foreign material, mustiness, excessive moisture, heating grain, or any factor that may render the grain of distinctly low quality.

Identification.—In general the spring wheats have a short, thick kernel as contrasted with the generally longer, more narrow kernel of the hard red winter wheats, with which they are frequently confused. Many varieties are sharply angled, with a wide open suture. A brush is nearly always evident, and in most varieties the kernels have their dorsal apex depressed to one side or the other, as illustrated in Fig. 55.

Fig. 55.—Typical lop-sided condition of spring wheat kernels as shown in cross section.

Some wheat varieties are bearded, others are beardless, and glume and straw color vary. These and several other characteristics are used in the identification of varieties.[1]

With the increased hybridization of spring and winter varieties, there is a tendency for a blending of characteristics, making it more and more difficult to classify certain varieties properly.

Varieties.—As indicated before, the market classification is an arbitrary one. Those varieties of wheat which are white in color are placed in the white wheat class regardless of whether they are spring or fall types.

Marquis wheat was developed in Canada by C. E. Saunders from a cross between Red Fife and Hard Red Calcutta and was introduced into the United States in 1912. The popularity of the new wheat grew until it is estimated by Clark[2] that in 1929 there were $11\frac{3}{4}$ million acres in the United States seeded to Marquis. Because of its high qualities as a milling wheat, it has long been used as a standard by which new spring

[1] Clark, J. Allen, and B. B. Bayles, Classification of Wheat Varieties Grown in the United States in 1939, *U.S. Dept. Agr. Tech. Bull.* 795, 1942.

[2] Clark, J. Allen, Improvement in Wheat, *U.S. Dept. Agr., Yearbook of Agriculture,* 1936.

wheat varieties are compared. Today, because of its susceptibility to black stem rust, Marquis is grown only in those areas where rust is not a factor. It has, however, been used as a parent to transmit its desirable characteristics to such varieties as Ceres, Hope, Reliance, Thatcher, Sturgeon, Comet, Reward, Canus, Apex, Renown, Mida, and many numbered wheats under test in the plant breeders' nurseries.

Other spring wheat varieties developed during recent years include Henry, Regent, Pilot, Rival, Newthatch, Mida, and Cadet.

No list of varieties in a reference book can long be up to date since the breeding program is moving rapidly to replace existing varieties with improved ones that possess superior agronomic qualities. The student should become familiar with those varieties recommended by his state agricultural experiment station. Only in this way can he hope to keep abreast of the procession of improvements made by the breeder and his associates in pathology and cereal technology.

Hard Red Winter Wheat.—Like the hard red spring class, these wheats are produced primarily for breadmaking purposes. The kernels when well developed under favorable conditions are hard and flinty and yield a flour of superior breadmaking qualities. As indicated in Chap. III, hard red winter wheat production centers in Kansas. There is, however, considerable overlapping between the hard red and the soft red types. This is particularly true in eastern Kansas and in Missouri, where varieties of both classes are grown and frequently occur as mixtures.

Grading.—Like the hard red spring wheats, the hard red winters are graded into subclasses, based on texture, as follows:

Dark hard winter	75 or more per cent of dark, hard, and vitreous kernels
Hard winter	More than 25 and less than 75 per cent dark, hard, and vitreous kernels
Yellow hard winter	Not more than 25 per cent dark, hard, and vitreous kernels

The numerical grades are determined on the basis of freedom from damage and foreign materials, very much the same as the wheats in the hard red spring class.

Identification.—Usually the kernels of varieties of hard red winter wheats are long and narrow with a relatively small germ. The kernel is uniform, and when placed with the suture side down the highest point on the dorsal side is in the center and not on the side as is common with hard red spring wheats. The seeds usually carry a brush. The suture

is relatively shallow as compared with hard red spring wheat, and the cheeks are rounded instead of angular.

Varieties may be bearded or beardless, but all possess red-colored kernels. If the kernels were not red, they could not be classed as hard red winter.

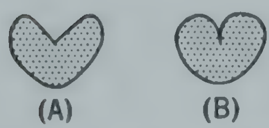


FIG. 56.—Cross section of kernel of (*A*) red spring wheat and (*B*) hard red winter wheat.

Varieties.—It is believed that the first hard red winter wheat to be grown in America was brought here by Mennonites who emigrated from Russia and originally settled in Kansas about 1873. These people brought seed of the Turkey variety which they had been growing in Russia. The new type of wheat, however, was of little more than local importance until M. A. Carleton of the United States Department of Agriculture, having noted the possibilities of the new wheat, went to Russia in 1900 and brought back several varieties and strains of hard red winter wheats.

FIG. 57.—Pawnee (*left*) and Blackhull (*right*) in the winter wheat variety plots at Lincoln, Neb. (*Courtesy of the Nebraska Agricultural Experiment Station.*)

Among the important introductions made by Carleton were Turkey, Kharkof, Crimean, and Beloglina, and from these original introductions were developed many of the present-day varieties. Like Marquis for the spring wheats, Turkey and Kharkof became the standards for evaluating new strains of hard red winter wheats.

Clark of the United States Department of Agriculture estimated that in 1929 Turkey wheat was grown on 15,925,677 acres in the United States, making it the leading variety of hard red winter wheats. Some

of the improved varieties are Blackhull, Kanred, Nebraska 60, Ridit, Michikof, Iobred, Minturki, Karmont, Montana 36, Ilred, and Newturk. Recent varieties of considerable promise developed cooperatively by the Kansas and Nebraska agricultural experiment stations are Comanche, Pawnee, and Wichita.

Soft Red Winter Wheat.—In general the varieties of soft red winter wheat possess a lower percentage of protein and a higher percentage of starch than the hard red spring or winter varieties. The quality of the flour is such that it does not make a dough with great elasticity. For this reason the soft red winter wheats are used more for cake flours and for the making of biscuits and similar products. Frequently the miller of the hard wheats uses the soft red winter types for blending purposes to produce the desired combination of strong and weak flours. As a rule the soft red winter wheats do not command so high a market price as the hard wheats. This is not always true, since in some years the demand is such that the soft wheats may sell at a premium. In general there is a tendency to feed a greater percentage of the soft wheats to livestock than is true for the hard red types.

The soft red winter wheats are generally grown in the southeastern and eastern areas of the country where the rainfall is greater and more humid conditions are prevalent. These environmental factors operate to produce a softer type of wheat, although genetically the soft wheats develop a less flinty grain than the hard wheats even when grown in drier areas more favorable to high-quality bread wheats.

Grading.—The soft red winter wheat class is divided into two subclasses:

Red winter
Western red

The subclasses are not based on the same characteristics as the hard red wheats but primarily upon the basis of the region where the wheat is grown. In general the soft red winter wheats grown west of the Great Plains area of the United States do not possess the same milling qualities as those grown farther east. Accordingly, the subclasses are used to separate the two groups. Included in the western red subclass are the red clubs, wheats of rather inferior milling qualities. Texture as such has no bearing on the subclasses, since most of the wheats in both groups are soft and starchy. Under some conditions, however, certain varieties may develop kernels that are rather hard and flinty and possess certain of the qualities of hard red winter varieties.

Identification.—As a rule the soft red winter wheat varieties have

a long kernel that is somewhat wider than that of the hard red winter wheats. Also, the germ of the soft red winter wheats tends to be larger. The suture is more open, resembling that of the hard red springs except that the cheeks are rounded in the soft red winters. The suture is very deep, and in most cases it is relatively easy to split a kernel of soft red winter lengthwise.

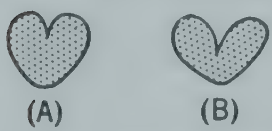


FIG. 58.—Cross section of kernels of (*A*) hard red winter wheat; (*B*) soft red winter wheat.

In the commercial grading of wheat it is necessary to learn to differentiate between the classes. Practice is essential to proficiency, but the use of a few points of general difference will enable even the uninitiated to develop a high degree of accuracy within a comparatively short time.

Varieties.—Probably there have been more varieties of soft red winter developed than are found in any other class of wheat. Certainly a contributing factor to this condition is the greater area and number of states growing the soft red winter wheats than is true for the other classes. Several important varieties have been grown for many years. Among the varieties that have been of most importance are Fultz, Fulcaster, Trumbull, Kawvale, Mediterranean, Red May, Leap, Poole, Currell, Nittany, Harvest Queen, Red Rock, Red Wave, Fulhio, Forward, Purplestraw, and Rudy. Newer varieties now being grown more extensively are Thorne and Clarkan. As was stated in the discussion of hard red spring wheat varieties, no list can be kept up to date, and it is necessary to check with each state experiment station to learn the varieties that are most satisfactory for a given section.

Durum Wheat.—The amber-colored durum wheats are grown in much the same region as the hard red spring wheats. All are spring planted, and the varieties tend to compete with hard red spring types. All durum varieties possess rather coarse heavy awns or beards. As a rule the quality of the grain is largely dependent upon the weather during growth and maturity of the crop. Humid, wet weather tends to produce a starchy, less hard kernel that is not so desirable as a market type as the harder more flinty grain. On the market a superior quality of durum may command a premium, while an inferior lot may sell at such a low price that it cannot compete under normal conditions with the more widely used hard red spring varieties of wheat.

Grading.—This class includes the varieties of *Triticum durum* which possess amber-colored kernels. The subclasses are based on the percent-

Hard amber durum. . 75 per cent or more hard, vitreous kernels
Amber durum. . . . . . . 60 per cent or more but less than 75 per cent hard, vitreous kernels
Durum. . . . . Less than 60 per cent hard, vitreous kernels

age of hard and vitreous kernels, as noted. While some of this wheat is fed to livestock, most of it is used to manufacture macaroni and similar products.

The presence of a spot or area that is light in color (starchy) places the kernel in the grouping "not hard and vitreous." The higher the percentage of hard and vitreous kernels, the more likely are the products to be satisfactory. As the durum varieties are not used for breadmaking purposes, mixtures of softer wheats, particularly soft red winter or white wheat, are especially undesirable, and but a small percentage is necessary to lower the market grade. Red durum mixtures operate in the same manner since they produce a dark-colored macaroni that is objectionable to the consumer.

Identification.—As a rule the durums do not possess a brush, a characteristic that aids greatly in learning to recognize them. The kernel is characterized by a distinctive pointed germ end and a tendency to have the edges of the cheeks flattened near the germ end. The appearance of the kernel is such that once one has learned to recognize it he should be able to identify the durums at a glance. Where the bread wheats have a dull, opaque appearance, the durums usually are clear amber or red, depending upon the variety.

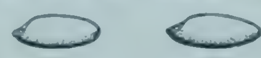


Fig. 59.—Outline of kernels of (*A*) wheat kernel and (*B*) Pentad, red durum. Note how Pentad is pointed at both ends of kernel.

An effort should be made to learn the physical characteristics of the durums as this is essential if one is to be able to separate them from other classes of wheat. If one does not know the physical characteristics, he will experience difficulty in recognizing the softer, starchy types of durum.

Varieties.—For many years durum wheat products have been the principal food of many southern Europeans, particularly Italians. A limited amount is eaten by Americans, but primarily as a diversion to the regular diet. As in the case of hard red winter wheat, about 1898, Russian emigrants to North Dakota introduced Arnautka durum wheat, where it was called Wild Goose, and shortly afterwards M. A. Carleton brought in seed from Russia, particularly the varieties Kubanka and Arnautka. Even today the Kubanka variety, many years after its original introduction, is the standard variety by which new durums are judged. A variety selected by the Minnesota Agricultural Experiment Station, distributed under the name of Mindum, has become a very important durum variety. It possesses those desirable semolina qualities so highly prized by millers. Recently developed varieties that possess considerable disease resistance and satisfactory milling qualities are Stewart and Carleton.

Red Durum Wheat.—The red durum varieties of wheat are not popular since they have no place in the manufacture of semolina products. Except for their color they are much the same as the amber durum wheats. The red durums are grown in the same sections as the amber durums and are raised primarily for livestock feeding. Like the amber durums, the varieties possess heavy awns and tend to have a weak straw.

Grading.—The red durum wheat class has no subclasses. The class includes all varieties of red durum wheat and may include not more than 10 per cent of wheats of other classes. The general grade requirements, except for wheats of other classes, are much the same as those for amber durum. In red durum wheat a total of 10 per cent of wheats of other classes is allowed in No. 1 Red Durum. Red durum is not important in the commercial grades except as it occurs as a very undesirable mixture in other wheats, particularly in the amber durum and hard red spring classes.

Identification.—If one can recognize the durum wheats it is simple to differentiate between amber and red durums. The dull reddish amber color of the red durum is distinct. When the seeds are starchy, the color is a very light shade of red and the inexperienced may have to resort to kernel morphology to make identification certain. The most common variety of red durum, Pentad, has a rather small kernel that tends to be pointed on both ends. The point is distinct on the germ end, and on the opposite end, lines drawn parallel to the sides of the kernel would meet a short distance from the end.

Varieties.—There are but few varieties of red durum wheat. No effort is being made to improve existing varieties as there is little or no place for the red durum types. The principal variety is Pentad (D-5), a variety that was introduced from Russia by H. L. Bolley of the North Dakota Agricultural Experiment Station in 1903. Another red durum variety, introduced from Russia about 1925, is Barnatka. This variety possesses a longer kernel than the Pentad. It has not been widely grown and does not occur so generally as Pentad.

White Wheats.—The designation of wheats as white refers to the lack of red pigment in the grain and has no relationship to their season of growth, since both spring and winter varieties are included in the class White Wheat. In the eastern sections of the United States a few white varieties are grown and managed much the same as the soft red winter wheats. In the mild areas of the Pacific Northwest many of the varieties are grown both as fall- or spring-sown types. Occasionally, a white-kerneled variety is grown in the hard red spring area, but such varieties

have not proved popular since they are marketed at a disadvantage in competition with the bread wheats. Although the eastern white wheats are often blended in with the soft red winters, most of the white wheats grown in America are used for cake and pastry flours, for crackers, and for the manufacture of breakfast foods. Generally they are softer in texture, possess a lower percentage of protein, and lack the gluten quality necessary for a good bread flour.

Grading.—All types and varieties of wheat fall into the class White Wheat. As would be expected, the qualities of different lots vary widely. The subclasses are as follows:

Hard white	75 per cent or more of hard (not soft and chalky) kernels
Soft white	Less than 75 per cent of hard kernels. Neither hard white nor soft white may contain more than 10 per cent of Sonora wheat or wheat of the white club varieties, either singly or in combination
White club	Includes the Sonora variety or wheat of the white club varieties, either singly or in combination. Shall not include more than 10 per cent of common white wheat other than Sonora, either singly or in any combination
Western white	Includes more than 10 per cent of Sonora or white club varieties, either singly or in any combination, and also contains more than 10 per cent of common white wheat other than Sonora

The grade requirements of the white wheats are much the same as for the other classes except that the durum wheats are especially discriminated against. Only one-half of 1 per cent of either durum or red durum, alone or in combination, is permitted in grade 1.

The hard white wheats are rather flinty and clear as contrasted with the soft, chalky appearance of the soft wheats. A different standard is used for hardness than is used for the red wheats, since rarely do white wheats exhibit the hard texture of hard red spring or winter wheats.

The variety Sonora is an especially undesirable wheat and is discriminated against in the grades as it yields an extremely inferior type of flour.

The club wheats may be of either winter or spring habit. The kernels tend to be small. Usually the grain is of poor quality for bread flour, and most of the wheat is milled for biscuit and pastry flour.

Identification.—To differentiate between red and white wheats it is necessary for one to be able to distinguish colors. A faded starchy red

wheat may at first glance look much the same as a white wheat. A good check is to examine the suture side, as the red color is most likely to be evident at this point.

The variety Sonora is small, with a small germ that is placed at a sharp angle.

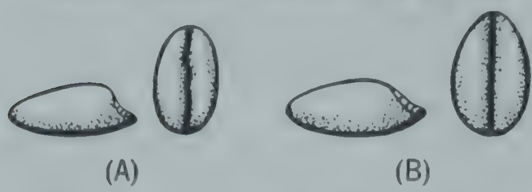


Fig. 60.—Outline of kernels of (*A*) club wheat and (*B*) *vulgare* or common wheat.

The club wheats, because of the crowded conditions in the multiflorate spikelets, tend to be small and laterally compressed. Usually the kernels have a narrow crease which often shows a tendency to be wavy and not straight as in common wheat varieties. The kernels are usually soft and have a chalky white appearance.

Varieties.—There are many varieties of white wheat, and they range widely in quality. They include both bearded and beardless varieties. The plants may resemble those of varieties of other classes except that the club wheats possess a club-shaped head, owing to the crowding of the florets within the spikelet.

Some of the more important varieties of white wheat have been Baart, Federation, Dawson, Rex, Goldcoin, White Federation, Florence (Quality), Pacific Bluestem, Dicklow, Bunyip, Sonora, Hard Federation, Defiance, Honor, and Onas. Newer varieties are Yorkwin in the East, or Federation in the Pacific Northwest, and Baart 38 and White Federation 38 in California. Leading varieties of white club wheat are Hybrid 128, Jenkin, Albit, and the newer Hymar.

Mixed Wheat.—This class includes all lots of wheat that contain more than 10 per cent of mixture. The mixtures may be of any type, but generally they include mixtures of classes that are grown in the same territory. For example, in some sections when the winter wheat is partially winterkilled the farmer will drill in spring wheat to thicken the stand. Naturally the resulting crop will be mixed and will be so graded on the market. In many sections the hard red and soft red winter wheats tend to become mixed in threshing, and many farmers grow the mixed classes. Where white wheats are raised they frequently become mixed with the red wheats. In the hard red spring wheat area the durums are likely to become mixed with the spring varieties.

Mixed wheats coming to the market are usually sold at a discount since their uses in milling are limited. For example, a mixture of hard red spring and durum varieties cannot be used for bread flour, neither can it be used for macaroni. In many cases such mixtures must be used for feed, and the resulting discount may be very great. It costs

no more to produce wheat that is free from mixture, and there is little or no excuse for the great percentage of marketed wheat that falls into the mixed class.

The Growing of Wheat

In Chap. V consideration was given to the general phases of the culture of the grain crops. Here it seems advisable to give attention to the

Fig. 61.—Drilling wheat on a well-prepared seedbed. *(Courtesy of the International Harvester Co.)*

problems of specific wheat-producing areas, with the variations in procedure that may apply to each section where wheat is grown. The problems of the wheat grower in the humid areas of the east are very different from those encountered in the dry sections of Kanass or the Dakotas. It seems advisable to consider each of the wheat-growing market classes by areas or sections where important.

Hard Red Spring Wheats.—Most of the hard red spring wheat is grown in the states of the Northwest (Chap. III), where generally the annual rainfall ranges from 12 to 30 in. In North Dakota, the leading spring wheat state, more than 75 per cent of the total rainfall comes during the growing months, so that a spring-sown crop can be produced with a minimum of total precipitation. In the drier areas, as in the

western Dakotas and the states of the Northwest, it is common to fallow the soil for 1 year before seeding a crop. Thus 2 years' rainfall is made available for the growing of the wheat crop.

Typical rotations in the more humid areas are (1) sugar beets, wheat, sweet clover; (2) wheat, sweet clover, flax; (3) wheat, barley, sweet clover, flax; (4) wheat, sweet clover, potatoes; and (5) wheat, alfalfa 2 to 3 years, cultivated crop. In the drier areas a year of fallow is followed by wheat. This is particularly true in the eastern part of Washington and Oregon and adjacent territory.

The general practice is to seed the wheat with a grain drill as early in the spring as possible, at as shallow a depth as practical to make certain that the seed is in moist soil. Usually by the time the soil is dry enough to seed it is advisable to put in the crop. The earlier the seeding, the better the opportunity to escape possible injury from hot weather at flowering time.

The importance of early seeding is illustrated by Dungan and Burlison.[1]

Table 33.—Date of Seeding Spring Wheat as It Affects Yield and Quality of Grain, Urbana, Ill., 1918–1922

Average date of seeding	Number of trials	Yield per acre, bu.	Test weight per bushel, lb.	Heads infected with scab,* per cent
Mar. 4	8	26.7	57.7	1.5
Mar. 15	8	22.5	56.4	3.4
Mar. 26	6	19.1	55.4	6.5
Apr. 8	5	18.9	56.1	14.8
Apr. 23	4	10.3		

* Scab data 1918 only.

In general, the earlier it is possible to seed, the better. Early planting often makes it possible for the crop to develop flowers and fill ahead of unfavorable environmental conditions such as hot weather.

Rates of seeding vary from 3 pecks in the dry regions to 6 pecks per acre in sections of higher rainfall. The better the seedbed preparation and the more favorable the soil conditions, the more likely one is to secure an adequate stand with a minimum rate of seeding.

Most hard red spring wheat is harvested with a combine, with much of it cut with a windrower and later combined from the swath. Con-

[1] Dungan, G. H., and W. L. Burlison, Spring Wheat: Adaptability for Illinois, *Ill. Agr. Expt. Sta. Bull.* 483, 1942.

siderable acreages are still harvested with a grain binder and threshed from the shock. In the drier areas a binder is seldom used, and the tendency is to combine the standing grain without the use of the windrower. A few farmers stack their bundles of wheat for later threshing, but these farmers are in the minority and commonly grow but little spring wheat.

Much of the hard red spring wheat is hauled directly from the thresher to the elevator for marketing. Some farms have storage space and store the wheat until it is believed the most favorable time to place it on the market. During the period of surpluses much wheat was stored in granaries under the government sealing program which guaranteed a minimum price to the producer.

Durum Wheats.—Both the amber and the red durums are grown in a relatively small area with only three states, North and South Dakota and Minnesota (Chap. III), being important producers. Very little of the total durum production is red durum, as this class of wheat usually sells at a discount and rarely is in demand. The producer of high-quality amber durum has an opportunity to earn a higher return since the market demand for superior durum is great. However, if poor durum wheat is produced, then the crop usually is less profitable than hard red spring wheat.

The place of the durums in the rotation is the same as that of hard red spring wheat. The grower of durum often grows the red spring wheat as well and tends to divide his acreage between the two classes of wheat. Many farmers do not like to grow the durum wheats because of the rough awns and the weak straw, which frequently results in lodging.

Seeding and harvesting practices for the durums are much the same as for the hard springs. Since the durum kernels are usually much larger, the rates of seeding are somewhat heavier. In most areas the rate for red spring is increased by one peck for the durum varieties.

Hard Red Winter Wheats.—Varieties of hard red winter wheat are grown under widely varying conditions, ranging from western to eastern United States south of the colder regions. Even in the cooler sections considerable winter wheat is produced. For example, Montana normally produces more than 10 million bushels of winter wheat annually.

The really important wheat state in the United States is Kansas, with a 10-year average production (1930–1939) of more than 131 million bushels and a production in the war year of 1945 of more than 200 million bushels.

In many sections, as in western Kansas, wheat is the principal crop and the so-called rotations are planned around wheat. In the driest

areas wheat is alternated with summer fallow. In more humid areas of dry farming in the Southwest, cotton or grain sorghums may be grown as the cultivated crop, followed by oats, winter wheat, and alfalfa. Farther to the east and north, winter wheat alternates with the other small grains, particularly oats. Many farmers prefer winter wheat as a companion crop for seeding grasses and legumes since it does not shade the ground as much as oats and is harvested earlier.

Seeding is normally done with a drill, with very large machines in general use on the big wheat farms. In the more humid areas where farms are not as large, the 10- to 12-ft. drills are more common. Some growers broadcast wheat, but this is not popular since it is generally believed that wheat planted by the broadcast method is much more subject to winterkilling and consequent reduction in yield. The seed is planted deep enough to reach moist soil and thus ensure rapid germination. In case the soil tends to be dry it frequently pays to use a cultipacker to promote firmness.

Call[1] in early studies reported that under the conditions prevailing in eastern Kansas early plowing was beneficial because of making available relatively large amounts of plant food, particularly nitrates, rather than for moisture storage. It does appear probable that in many seasons the checking of weed growth with the early plowing should result in the storage of more water in the soil than would be true for later plowing.

Early seeding has been shown to be favorable to good yields, but seeding in most of the winter wheat area is conditioned by the Hessian fly. It is necessary to delay planting until after the Hessian fly has laid its egg (Chap. VIII). In more northern areas where the Hessian fly is not prevalent, it is usual to seed winter wheat early enough to ensure good growth before the coming of cold weather.

Those farmers who plan to use winter wheat as supplementary pasture often seed earlier to secure greater growth. Generally, fall pasturing is inadvisable as it is likely to result in serious reduction in yield. Controlled spring grazing of winter wheat may have little or no effect on yield, provided that the crop is not grazed heavily.

In comparable areas winter wheat is seeded at a lower rate than is spring wheat. Rates vary from 3 to 5 pecks per acre, with the heavier rates used in the more humid sections. Jardine[2] reported that the later

[1] Call, L. E., The Effect of Different Methods of Preparing a Seed Bed for Winter Wheat upon Yield, Soil Moisture and Nitrates, *J. Am. Soc. Agron.*, **6**: 249–259, 1914.

[2] Jardine, W. M., Effect of Rate and Date of Sowing on Yield of Winter Wheat, *J. Am. Soc. Agron.*, **8**:163–166, 1916.

the seeding of winter wheat, the greater was the quantity of seed required to secure an adequate stand. The earlier seedings provided time for more stooling and a consequent thickening of the stand.

In the large winter wheat-producing areas the combine is most widely used. The header, a machine that removes only the heads of the wheat, is but little used. On the smaller farms the binder is still used extensively, and shock threshing is followed. Even here the small combine has increased greatly in popularity and is replacing many of

Fig. 62.—The small combine has come into extensive use. (*Courtesy of the J. I. Case Company.*)

the binders. Where the thresher is used there has been a decided shift to smaller machines, which are much more numerous in a community, thus making it possible to complete threshing within a shorter period and with a smaller crew. Some farmers speed operations by frequent settings of the threshing rig so as to reduce the time required to bring the bundles to the machine. In some cases the bundles are moved to the machine with a sweep rake mounted on the front of a tractor, enabling one man to bring in more shocks than would normally be moved by two men with wagons. In the eastern sections of the winter wheat belt some farmers stack their wheat near the buildings and thresh later in the season. This practice, however, appears to be much less popular

with the passing of time. In these sections an objection to the combine is the scattering of the straw, since these farmers desire to use it as bedding for their livestock.

Much of the harvested wheat is hauled to the local elevator or is stored in granaries on the farm. In the dry areas, when the crop is being threshed more rapidly than it can be moved, it is not uncommon to pile the wheat in huge heaps. Such a practice may result in considerable loss, but is resorted to in dry sections. On smaller farms the wheat is sold at once or is stored in bins on the farm for later marketing or feeding to livestock.

Soft Red Winter Wheats.—The soft red winter wheats are predominantly wheats of the humid sections of the United States, roughly to the east of the hard red winter wheat belt and centering in Ohio, Indiana, and Illinois. Here the annual rainfall ranges from about 35 to 45 in., and the humidity is much higher than is found in the states farther west. The warm, drying winds of the southwest are absent, and the cereal crops are more likely to be injured by hot, humid weather at the time of flowering. Diseases, particularly rusts, find more favorable environment in the soft red winter wheat area. All these factors combine to favor a wheat of a more starchy texture, one that is lower in percentage of protein and less suitable for breadmaking. On the whole, the varieties of soft red winter wheat are much better performers under these environmental conditions than are the hard red winter types.

Much of the region where soft red winter wheat is grown is known as the *corn and winter wheat belt.* This means that winter wheat is grown in rotation with corn. It is not uncommon to see farms where the corn has been cut, bound, and shocked and the winter wheat drilled in the corn stubble following the preparation of a seedbed. Common rotations are (1) corn, wheat, red clover; (2) corn, wheat, clover, and timothy (the crop may be harvested for hay the first year and used for pasture the second); (3) corn, oats, wheat, red clover; and (4) corn, soybeans, wheat, clover. The Indiana station[1] has found that wheat after properly inoculated soybeans will usually outyield wheat after corn. Of course there exist many modifications of the type of rotations given. With the greater use of the soybean, a common rotation is corn, soybeans, wheat, clover.

Where wheat follows corn it is possible to prepare the seedbed by disking and harrowing the land and drilling in the wheat, and the same plan may be followed when wheat follows soybeans. Usually the season

[1] Wiancko, A. T., and C. E. Skiver, Wheat Production in Indiana, *Purdue Univ. Agr. Expt. Sta. Circ.* 237, 1938.

is long enough so that it is possible to seed the wheat after harvesting the corn or soybean crop. A few farmers seed the wheat between the rows of standing corn and then harvest the corn later. This method is not so suitable under most conditions, as lower yields result. As in the hard red winter wheat sections, it is necessary to delay seeding until after the Hessian fly-free date, as determined by the state entomologists each year.

In the soft red winter wheat states the use of commercial fertilizers is more common than farther to the west. Over a period of 20 years the Purdue station was able to increase the average annual yield of wheat at La Fayette by 9.1 bu. per acre by applying 300 lb. of 2-12-6 fertilizer per acre. The same station found that in a corn, wheat, clover rotation applying the manure in the winter on the wheat as a light top dressing was most profitable.

Seeding rates are somewhat higher than in the West, and probably the most common rate is 6 pecks per acre.

The binder is widely used in this area, but many combines have been introduced. Here there is a need for considerable straw, and many farmers prefer the binder for this reason. With greater rainfall, shock threshing has certain advantages over the combine. Many farmers stack their grain near the buildings and blow the straw into the barn or into a heap near the buildings. A common practice is to construct a framework of poles and wire and, by covering it with threshed straw, make a very satisfactory shed for livestock.

The farms are generally smaller, and most of them carry livestock. Much of the wheat is stored in bins on the farm, and much is fed to livestock. While the soft red winter wheats are not used directly for the best bread flour, they often are in great demand for blending with the stronger wheats. In many areas, particularly in the South, the soft red winter flours are widely used for the making of hot breads such as biscuits. In many homes the biscuit is a regular article of diet, largely replacing white bread in the menu.

The White Wheats.—Both winter and spring varieties of white wheat are of importance. With the principal areas of production in the Far West and in northeastern United States, nearly all the club wheats are found in four states, Washington, Oregon, California, and Idaho. In the East most of the white wheat has been produced in Michigan and New York, where most of the varieties are fall-sown and in general possess many of the characteristics of the soft red winter wheats.

The general cultural practices for the white wheats are much the same as for the red springs or soft red winters, depending upon the area

in which they are grown. The club wheats owe much of their popularity in the West to the ability of the plants to stand until dead ripe without shattering of the grain. This makes them especially suitable for harvesting with the combine.

Emmer.—This wheat is grown to but a limited extent in this country. The principal acreage is in North and South Dakota where the crop is grown for feeding to livestock. Since the wheat retains its hull when threshed, the yields appear larger than actually occurs, as about 20 per cent of the total yield is hull (glumes) and has little or no feeding value. Most experimental trials indicate that emmer has little or no place in American agriculture.

Both winter and spring varieties are available, but the spring emmer is the one usually grown. The principal variety, Vernal, because of its disease resistance, has been used in the improvement of spring wheat varieties. The emmer wheats have a weak straw and frequently lodge before harvest.

The culture of emmer is much the same as that of other wheats. The weight per bushel is 40 lb., and the usual rate of seeding is 6 to 8 pecks per acre. The crop is harvested in the same way as other wheats, using either the binder or the combine.

Spelt or Speltz.—This wheat, often confused with emmer, also retains its glumes when threshed. Both winter and spring and bearded and beardless varieties are grown. It is of little importance as a commercial crop. A small acreage, primarily of the variety Alstroum, is grown in the Virginias and in Oregon. The bushel weight of spelt is 40 lb., and the grain carries 20 to 30 per cent hull. Culture is much the same as that of other wheats, with a seeding rate of 8 to 12 pecks per acre, usually sown in the fall. The harvested grain is used for livestock feed and has no value for flour making.

Polish Wheat.—This wheat, characterized by its very long heads, often 6 or 7 in. in length, has no place in American agriculture. As it resembles rye in some respects, it has been sold occasionally as Giant Rye. The grain is of no value for milling, being about equal to ordinary wheat for livestock. It is important to be able to recognize this wheat since it is often sold to unsuspecting growers as a new and improved type of wheat.

Poulard Wheat.—This is another wheat of no value in the United States. It is characterized by a very large head, which may or may not be branched. The stems of the plant are solid, not hollow as in common wheats. Both spring and winter types exist, but neither has yielded as well as club, common, or durum wheats grown under the same conditions.

The flinty grain is of value only for feeding to livestock. Poulard has been sold at exorbitant prices to growers, who were led to believe that it possessed unusual yielding ability.

Einkorn Wheat.—The name of this wheat is of German origin, meaning one seed. Like emmer and spelt, it retains its glumes when threshed. The plant is winter in habit and has never been grown commercially in the United States.

The Milling of Wheat

Most of the wheat grown in the United States is processed into flour for later use by the baker in making white bread. Although varieties differ in qualities for breadmaking, in general the hard red spring and hard red winter wheats are considered the most satisfactory for strong bread flours. The steps followed in the milling of wheat by the roller-milling process are of considerable interest.

Preparing the Wheat.—As the grain reaches the flour mill it usually contains weed seeds, dirt, trash, and other types of foreign material that must be removed by a process of thorough cleaning. If smut is present in abundance, it is necessary to scour the wheat to remove the spores.

Tempering the Wheat.—After the wheat is cleaned, water is added by a process of tempering that toughens the bran to make it more easily separated from the endosperm.

Breaking the Wheat.—Next the tempered wheat is passed several times between a series of corrugated rolls for the purpose of breaking the kernel and separating the bran.

Bolting.—Following each break a portion of the endosperm is separated by passing it through a series of very fine screens which are rapidly shaken in a circular motion.

Purification.—The sifted flour is purified by air currents to remove the light pieces of bran flakes which tend to adhere to the flour particles.

Reduction.—Next the middlings are passed through smooth rolls which reduce them to a very fine state. This further effects the separation of the bran from the endosperm. Separations of the flour are made into different grades based upon relative purity. The germs that are resistant to breaking tend to flatten when passed through the smooth rolls and are readily removed from the flour for later use in processing various types of livestock feed. Also, the bran separation is sold for animal feeds, with limited amounts entering into human food. The streams of flour coming from the mill vary in the amount of bran and germ particles that are not separated. On the basis of their purity the flours are graded.

Bleaching.—Freshly milled hard red wheat flour often is yellow in color because of the presence of carotene. Since the American people generally prefer white flour and bread, the yellow color is removed by various processes known as *bleaching*. Several types of bleaching agents are used to removed this yellow color. As this adds to the cost of milling, the miller favors a wheat variety with a low percentage of yellow color, and the plant breeder considers this an important factor in his program of improvement.

Grades of Flour.—The large flour-milling companies sell their flours according to the quality of the product. Daily tests are made of the quality of the flour being milled, and experimental loaves of bread are baked as a final test. Only that flour which meets their exacting requirements goes out under the label of the firm's best grade of flour. Lower quality flour may be marketed under the name of a distributing organization, or it may be sold without any reference to the manufacturer. Naturally, the poorer grades of flour sell for a lower price and usually are found in most stores along with the more expensive, higher quality flours.

The best grade, which is the portion of the mill stream most highly refined, is known as *patent flour*. The name *clear* is used for that portion of the flour that remains after the patent separation. The lowest grade carries considerable bran and is used primarily for the feeding of livestock. The lower grade products, which vary in composition according to the separations, are sold as bran, middlings or shorts, and red dog flour.

Flour products have been defined by the United States Department of Agriculture as follows:

Flour, wheat flour, white flour, is the fine-ground product obtained in the commercial milling of wheat and consists essentially of the starch and gluten of the endosperm. It contains not more than 15 per cent of moisture, not less than 1 per cent of ash, and not more than 0.5 per cent of fiber.

Whole-wheat flour, entire wheat flour, graham flour, is the product made by grinding wheat and contains, in their natural proportions, all the constituents of the cleaned grain.

Amount of Flour from Wheat.—In general, the heavier the test weight of wheat, the greater is the yield of flour, although this is not an absolute rule in the heavier weights. An average lot of good-quality bread wheat should yield about 70 per cent flour, which means that a bushel of wheat testing 60 lb. could be milled into 42 lb. of flour.

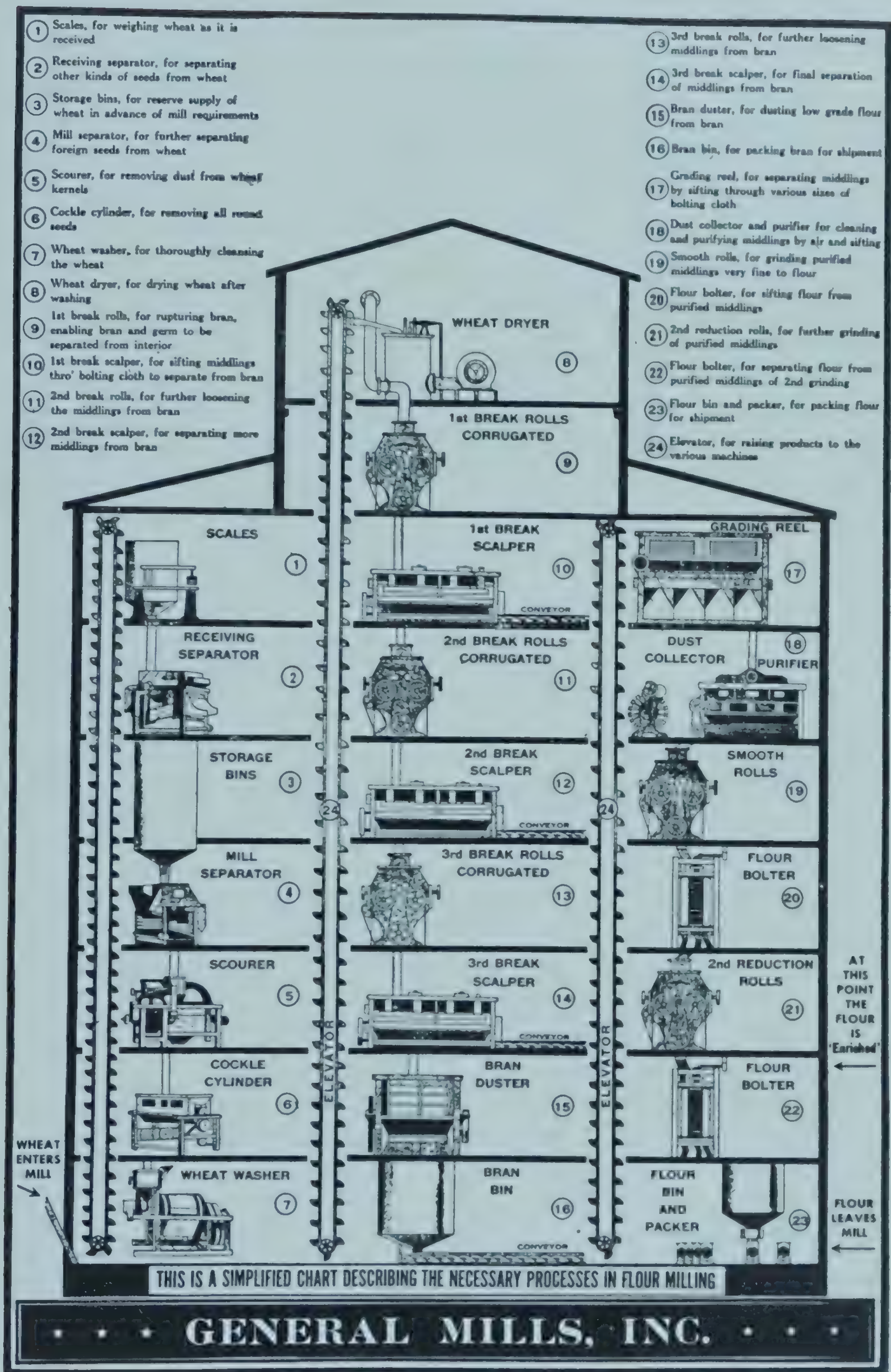


FIG. 63.—The process of milling is a complicated one, carried out under precise control to produce the best possible product. (*Courtesy of General Mills, Inc.*)

Winter Hardiness and Wheat

The problems of winter hardiness are so great in those areas where winter wheat is grown that they are deserving of especial consideration. By far the greater acreage of the wheat produced in the United States is fall-sown and is subjected to the many hazards that accompany winter temperatures. The winter injury of fall-sown crops is not necessarily a matter of location from north to south, as hazards may be much greater in an area that experiences moderate winter temperatures but is subject to considerable freezing and thawing than in a section where the winter temperatures are much lower but tend to remain relatively stable.

Hardening Off.—Plants that are able to survive winter temperatures go through a series of physiological changes that enable them to withstand the unfavorable environment, changes that have been called the process of *hardening off*. If freshly germinated wheat seedlings are exposed to very low temperatures they may be killed almost immediately, yet if these same seedlings are gradually subjected to lower and lower temperatures nature makes it possible for them to change so as to be uninjured even at very low tempertures. Not all plants have the ability to harden off in this manner. Varieties of winter wheat differ widely, as some varieties are much better able to withstand cold temperatures than others.

Theories of Winterkilling.—Several theories have been advanced in attempts to explain the causes of winterkilling. The principal theories are (1) death by freezing, (2) physiological drought, (3) heaving, and (4) smothering.

Death by Freezing.—Many workers believe that injury results from the formation of ice crystals within the cells or in the intercellular spaces. Many very winter-hardy plants are known to undergo a change in their cell contents with the advent of winter, and the increased concentration is believed to prevent the formation of ice with the coming of winter and its lower temperatures.

Physiological Drought.—The phenomenon of physiological drought is closely related to that of death by freezing. It is believed that the plant dies from a lack of water induced by the lowered temperatures. Klages[1] found that hardy varieties of winter wheat exhibited comparatively small leaf areas in the fall while the less hardy varieties had greater leaf area exposed. In the freezing process the coagulation of the cell sap causes a withdrawal of water, which results in a process of desiccation believed responsible for much of the winterkilling.

[1] Klages, K. H. W., Metrical Attributes and the Physiology of Hardy Varieties of Winter Wheat, *J. Am. Soc. Agron.*, **18**: 529–566, 1926.

Heaving.—This is the action of the soil following periods of alternate freezing and thawing. In areas subject to wide fluctuations in winter temperatures much damage may occur from heaving. During the day when the sun shines, the ground thaws; at night it freezes. The tendency of the soil to fold and heave pulls the plants from the soil and may cause their destruction. The use of a cultipacker to refirm the soil is advisable to aid in correcting the damage. The colder areas do not usually experience this condition, except possibly for a short time in the spring of the year.

Smothering.—This is a result of shutting off the oxygen supply and usually occurs early in the fall or late in the winter when ice sheets cover the field. Water standing for a considerable period will cause much the same injury. Some investigators question the cause of injury and believe that damage results from carbohydrate exhaustion rather than from a lack of oxygen. Sometimes it is practical to correct the condition by running a disk or other heavy implement over the field to break the ice crust, but usually it is impractical to attempt to correct the situation.

RYE

Rye comes near to being an all-state crop since it is grown to some extent in nearly every part of the United States. The extreme hardiness of the plant and its ability to perform well even when the soil is rather infertile has led to its wide use on the soils that are sandy and not generally suitable for the production of most other grain crops.

In many parts of the world rye fills much the same place as wheat does in America, being used primarily for bread. In this country, however, the major use is for livestock feeding, its use for human food being incidental.

Botanical Classification

Rye is a member of the grass family and the cultivated species *Secale cereale* L. Carleton[1] states that Hackel has divided rye into two species:

Secale fragile, Bieberst.
Secale cereale L.

S. fragile is an annual grown to some extent in southwestern Asia, whereas *S. cereale* is the species grown in America. It is believed that *S. cereale* came from *S. montanum* Gus., a wild perennial form found in southern Europe and central Asia.

[1] Carleton, M. A., "The Small Grains," The Macmillan Company, New York, 1919.

The cultivated species has seven pairs of chromosomes and has been crossed with wheat in an attempt to combine the hardiness of rye with the quality of wheat, but no successful varieties have been produced.

Agronomic Classification

Rye is used for grain, pasture, and to a limited extent for hay. It is not uncommon for farmers in rye-producing areas to use the crop for both pasture and grain. Where this is done it is best to graze lightly, or the yield may be reduced materially.

Rye straw is very suitable for bedding and packing but is not so desirable as oat straw as a roughage for livestock since it is less palatable and is of lower feeding value.

Most rye is winter sown and is known as *fall* or *winter rye*. However, spring types do exist but are not grown extensively, for as a rule there is little demand for a spring rye. If the farmer plans to grow a spring grain he is likely to choose one that is superior to rye. With the fall rye it is a different question, since this type is usually better able to produce than any other grain that could compete with it for the use of the land.

Market Classification

Rye is marketed under the official Grain Standards of the United States Department of Agriculture. The standards define rye as "any grain which, before the removal of dockage, consists of 50 per cent or more of rye, and not more than 10 per cent of other grains for which standards have been established under the provisions of the United States Grain Standards Act."

All rye is graded in one class, regardless of variety or colors, which range from colorless or white to greens and dark purples. There are four numerical grades and Sample Grade, based upon the weight per bushel, percentage of damaged grain, and the percentage of foreign material remaining after the removal of the dockage.

Special grade designations are included for rye that contains smut, garlic, weevils, or ergot. The presence of ergot is especially undesirable since it is poisonous when fed in quantity. Ergot no doubt is largely responsible for much of the dislike that farm animals usually show for rye as a feed.

Varieties of Rye

Fewer varieties of rye have been developed than for most other grain crops. Probably less effort has been put into the improvement of rye varieties than is true for the other grains. There may be several

reasons for this, but certainly one important reason is that the crop is usually grown in areas where the more profitable grains are not suited.

A few of the more important varieties are the so-called *Swedish type*, a mixed rye, from which many varieties have been developed: Dakold, Rosen, Wisconsin Pedigree 2, Petkus, and Emerald. In the South,

FIG. 64.—Balbo rye has proved especially suitable as a pasture crop. (*Courtesy of B. M. King, Missouri Agricultural Experiment Station.*)

Abruzzes has been important for many years. A new variety, Balbo, has proved especially valuable for pasture.

USES OF RYE

The most important part of rye is the grain, which is fed to livestock. It enters into the manufacture of alcoholic beverages and various foodstuffs. Compared with wheat, relatively little rye is consumed as bread. As a livestock feed, rye is unpopular since the grain tends to form a sticky mass in the animal's mouth. The common presence of ergot bodies in the grain also makes it unpalatable and, if present in quantity, poisonous as a feed.

Growing rye makes a very good pasture crop, and many farmers use it to supplement their permanent pastures. The crop may be pastured both in the fall and in the spring of the year.

The straw of rye has relatively little value except for livestock bedding or in the manufacture of paper.

Culture

The culture of rye is much the same as that given for winter wheat. Since the plant is hardier it can be grown much farther north than winter wheat and will do well on light, sandy soils that would be unsuited to wheat production. For these reasons most rye is grown on submarginal lands where it usually is not so satisfactory for other grain crops. Many of the sandy areas in both the North and the South are seeded to rye in preference to other grain crops.

Review Questions

1. Why is it of value for the student of agronomy to know the common wheat species?
2. How can one recognize emmer, einkorn, and speltz?
3. What are the leading wheat-producing countries?
4. How is the protein content of wheat related to climate?
5. How does wheat affect your life?
6. Why is wheat not fed more generally to livestock?
7. Of what importance is straw on the average farm?
8. What are the advantages of market grades?
9. How do the kernel characteristics of hard red spring wheat differ from those of hard red winter?
10. What is meant by bearded and beardless?
11. Why is Marquis wheat not grown so extensively as in earlier years?
12. What type of wheat is grown in your area?
13. What use is made of this wheat?
14. Why are the durum wheats of no value for bread flour?
15. What uses are made of the white wheats?
16. What man was largely responsible for the introduction of hard red winter wheat into America?
17. Why are soft red winter wheats rather than the hard wheats grown in southeastern United States?
18. What uses are made of the soft red winter wheats?
19. How can one recognize a durum wheat kernel in a mixture?
20. What use is made of red durum wheat?
21. What is club wheat?
22. Locate the principal wheat belts.
23. Give a rotation for your area, including wheat.
24. How much wheat is seeded per acre in your section?
25. What are the advantages of the combine?
26. What use is made of emmer?
27. Outline the steps in milling wheat.
28. Why is it necessary to bleach wheat flour?
29. What are the causes of winterkilling of wheat?
30. Name the different types of flour.

31. Why is rye unpopular with livestock feeders?
32. What advantages can you see in a uniform-colored rye?
33. Outline a program for the use of rye as a pasture crop.

References

Ausemus, E. R., E. C. Stakman, E. W. Hanson, W. R. Geddes, and P. P. Meredith: Newthatch Wheat, *Minn. Agr. Expt. Sta. Tech. Bull.* 166, 1944.

Bailey, C. H.: "The Chemistry of Wheat Flour," Reinhold Publishing Corporation, New York, 1925.

———: Protein Surveys of American Hard Spring and Soft Winter Wheats, *Minn. Agr. Expt. Sta. Tech. Bull.* 147, 1941.

Clark, J. Allen, and B. B. Bayles: Classification of Wheat Varieties Grown in the United States in 1939, *U.S. Dept. Agr. Tech. Bull.* 795, 1942.

Etheridge, W. C., and C. A. Helm: Wheat in Missouri, *Mo. Agr. Expt. Sta. Bull.* 398, 1938.

Gaines, E. F., and E. G. Schafer: Wheat Varieties in Washington in 1939, *Wash. Agr. Expt. Sta. Bull.* 398, 1941.

Kiesselbach, T. A., O. J. Webster, and K. S. Quisenberry: Varieties of Oats, Barley and Spring Wheat in Nebraska, *Neb. Agr. Expt. Sta. Bull.* 328, 1940.

Klages, K. H. W.: Winter Wheat Production in South Dakota, *S. D. Agr. Expt. Sta. Bull.* 276, 1933.

Levitt, J.: "Frost Killing and Hardiness of Plants," Burgess Publishing Company, Minneapolis, 1941.

Miller, L. B., and F. C. Bauer: Soil Treatments for Winter Wheat, *Ill. Agr. Expt. Sta. Bull.* 503, 1944.

Quisenberry, K. S., O. J. Webster, and T. A. Kiesselbach: Varieties of Winter Wheat for Nebraska, *Neb. Agr. Expt. Sta. Bull.* 367, 1944.

Reitz, L. P., and H. H. Laude: Comanche and Pawnee: New Varieties of Hard Red Winter Wheat for Kansas, *Kans. Agr. Expt. Sta. Bull.* 319, 1943.

Robertson, D. W., J. J. Curtis, D. Koonce, J. F. Brandon, and O. H. Coleman: Winter Wheat Production in Colorado, *Colo. Agr. Expt. Sta. Bull.* 470, 1942.

———, J. F. Brandon, H. Fellows, O. H. Coleman, and J. J. Curtis: Rate and Date of Seeding Winter Wheat in Eastern Colorado, *Colo. Agr. Expt. Sta. Bull.* 472, 1942.

Salmon, S. C.: Climate and Small Grains, "Climate and Man," *U.S. Dept. Agr., Yearbook of Agriculture,* 1941.

Stephens, D. E., R. B. Webb, and J. F. Martin: Wheat Varieties for the Columbia River Basin of Oregon, *Ore. Agr. Expt. Sta. Bull.* 308, 1932.

Stoa, T. E., L. R. Waldron, R. H. Harris, and L. D. Sibbitt: Varieties of Wheat for North Dakota, *N. D. Agr. Expt. Sta. Bimonthly Bull.*, Vol. 8, No. 3, 1946.

Suneson, C. A., and F. N. Briggs: Wheat Production in California, *Calif. Agr. Expt. Sta. Bull.* 659, 1941.

Swanson, C. O.: "Wheat and Flour Quality," Burgess Publishing Company, Minneapolis, 1938.

Waldron, L. R., R. H. Harris, T. E. Stoa, and L. D. Sibbitt: Protein and Quality in Hard Red Spring Wheat with Respect to Temperature and Rainfall, *N. D. Agr. Expt. Sta. Bull.* 311, 1942.

Wiancko, A. T., and C. E. Skiver: Wheat Production in Indiana, *Purdue Univ. Agr. Expt. Sta. Circ.* 237, 1938.

CHAPTER X

OATS

Probably no other agricultural grain crop, in view of its contribution to man's welfare has been less appreciated than oats. For years it has been shown by careful cost-account records that oats do not rank high as a cash crop, yet in spite of this damaging evidence they rank second only to corn in total bushels produced in America. One may well ask for an explanation of this seeming anomaly. The explanation is rather complex and involves many factors. In general, the grains compared with oats in cost records were grown on better land than the oats. It would appear that factors of great importance are the relative sureness of the oat crop under a wide range of soil and climatic conditions and the suitability of the grain and straw to the needs of many of the nation's farmers.

Most of the oats produced in America are not grown for sale as cash grain but are fed on the farms. The suitability of the crop in the average rotation has also led to its rather general acceptance in the grain-producing areas, and it is grown widely from the south to the north and from the east to the west. Of the small grain crops it is the most widely grown.

CLASSIFICATION OF OATS

Oats may be classified on the basis of botanical characteristics, season of growth, and the designations used in the grain markets.

Botanical Classification.—The oat plant is a member of the Gramineae family of the genus *Avena* and according to Stanton[1] is derived chiefly from two species, the wild oat (*Avena fatua* L.) and the wild red oat (*A. sterilis* L.). The various species may be classified on the basis of their chromosome numbers.

A. brevis,[2] also known as the *short oat*, is of little importance as a cultivated plant, being grown to a limited extent in certain parts of Europe. It is differentiated primarily from other minor species by the

[1] Stanton, T. R., Superior Germ Plasm in Oats, *U.S. Dept. Agr.*, *Yearbook of Agriculture*, 1936.

[2] Liberal reference has been made to W. C. Etheridge, A Classification of the Varieties of Cultivated Oats, *Cornell Univ. Memoir* 10, 1916.

two short toothlike points of the lemma. As the name implies, the grains or lemmas also are very short and small. *A. brevis* is truly a very distinct and easily identified species.

TABLE 34.—IMPORTANT SPECIES OF AVENA

Pairs of chromosomes		
7	14	21
A. brevis Roth *A. strigosa* Schreb. *A. wiestii* Steudel *A. nudibrevis* Vav.	*A. barbata* Pott. *A. abyssinica* Hochst.	*A. fatua* L. *A. sativa* L. *A. sativa orientalis* Schreb. *A. nuda* L. *A. sterilis ludoviciana* Dur. *A. byzantina* C. Koch *algeriensis* Trabut

A. strigosa, also known as the *sand oat*, like *A. brevis*, is not important as a cultivated oat, although some improved types have been developed in England. It may be differentiated from *A. brevis* by its elongated lanceolate two-pointed lemma, while that of *A. brevis* is short and blunt. *A. wiestii*, similar to *A. strigosa* and sometimes referred to as the *desert oat*, likewise is of little importance. It differs from *A. strigosa* in having somewhat shorter and less distinct lemma points. *A. wiestii* resembles *A. barbata* in having very hairy lemmas. In fact before the chromosome number was known, it was considered a subspecies or variety of *A. barbata* by some early botanists.

A. barbata, the wild type found in the Pacific Coast states, is an important range grass in California. This rather distinct species is known as the *slender oat*. The principal distinguishing characters of *A. barbata* are its fine, tall, weak culms, which show a decumbent habit of growth during the life of the plant. Its very long and exceedingly slender hairy lemmas are further outstanding differentiating characters.

A. abyssinica, grown for forage to a limited extent in the desert regions of Ethiopia and southern Arabia, is more like *A. sativa* than any of the so-called *minor* species. The Abyssinian oat is one of the earliest maturing of all the oat species and is grown at high altitudes in Ethiopia. It is characterized by having twisted and geniculate awns on both florets of the spikelet, long hairy rachilla, and nonhairy lemmas.

FIG. 65.—Panicles and florets of different types of oats. On left is an equilateral (spreading or open) panicle; on the right, a unilateral (side or horse-mane) panicle. The florets represent primary and secondary grains of different types of oats. At the bottom left are pictured common wild oats (*Avena fatua*); at the right wild red oats (*A. sterilis*). (*Courtesy of T. R. Stanton, U.S. Department of Agriculture.*)

A. fatua is the common wild oat of the northwestern oat-producing states, where it is a most troublesome weed. The grain is characterized by the separation of the lower lemma from the rachilla or pedicel so as to leave a distinct horseshoe-like cavity (suckermouth) at the base of the

lemma. Usually it carries a heavy tuft of fine hairs at the base of the lemma and on the rachilla of the secondary floret. Usually, both florets of the spikelet carry rather strong, twisted and geniculate or bent awns. The mature lemmas may be hairy or nonhairy and may be yellowish-white, gray, grayish-red, or brownish-black in color.

A. sativa, the common oat to which species most of our present-day cultivated varieties belong, is of great economic importance. Generally, the base of the lemma is more or less solidified, the secondary oat separates from the primary so as to leave the rachilla attached to the primary, and in many varieties few if any hairs are found at the base of the lemma.

A. sativa orientalis, sometimes referred to as the *side oat*, is very much like *sativa* except that the branches of the panicle tend to develop to one side rather than in the equilateral manner. Also, several varieties of side oats possess what Etheridge refers to as an *abnormal node*, a hollow stem at the base of the panicle rather than a solid one as found in *sativa*. Side oat varieties are of much less importance than formerly, owing to their inferior yielding power as compared with most varieties having equilateral panicles.

A. nuda, or the naked oat, possesses a lemma and a palea which are of light texture similar to that of the outer glumes, and neither adheres closely to the caryopsis, so that in threshing they are readily separated leaving the naked grain. While the common oat usually has two to three florets per spikelet, the hull-less or *nuda* varieties may develop several fertile florets extending well beyond the limits of the outer glumes.

A. sterilis, the wild red oat, is believed to be the progenitor of our cultivated red oat varieties. The basiliar connection of the primary grain articulates or separates much like that of *fatua*. In general, when the primary and secondary grains are separated, the rachilla adheres to the secondary and not to the primary as in sativa. The wild red oat is characterized by its very large hairy lemmas with large basal cavities (suckermouths), numerous long basal hairs, and very long, strongly twisted and geniculate awns.

A. ludoviciana is a slightly less primitive form of *sterilis*, usually possessing fewer hairs on the lemma and somewhat shorter awns.

A. byzantina is a descendant of *sterilis* and is represented by many varieties in the South, most of which are red in color. This species differs from *sterilis* primarily in having glabrous lemmas, weak non-twisted awns, and fewer basal hairs.

A. byzantina algeriensis, also from *sterilis*, is similar to *A. byzantina*,

although usually having slightly longer glumes and lemmas. It is grown principally in Argentina, Australia, and northern Africa.

Identification of Varieties.—The various oat species have been described and in general may be recognized by the characters given. The colors of oat grains include white, straw-colored, and various shades of yellow, red, black, and gray. Due to environmental influences, the colors do not always develop. For example, a red oat may appear to be white or yellow or even gray. One of the best means of identification of the cultivated red oats is to observe the base of the primary oat and the manner in which the secondary kernel articulates or separates from the primary.

FIG. 66.—Mode of floret separation in the two major species of oats. Left, common (*Avena sativa*); right, red (*A. byzantina*).

Usually the wild oat is more slender and carries a higher percentage of hull than the cultivated species. It is common for intermediate types, known as *fatuoids* or *false wild oats*, to occur in cultivated varieties. These have been somewhat more prevalent in the new varieties derived from Victoria-Richland crosses than in old standard varieties. As a rule, such fatuoids are rather plump and their size approximates that of the cultivated varieties. They also have the color of the variety in which they occur. A good measure of the true identity of a fatuoid is to place it on a blotter to germinate. If it is a true wild oat it will exhibit a longer period of dormancy and usually will not germinate until several months of after-ripening have occurred.

It is extremely difficult to identify the various cultivated varieties. Color is a fairly safe means of separation, but white varieties subjected to rain may carry a pronounced yellow shade. Gray oats usually exhibit the greatest concentration of color on the palea, and it is not uncommon for a gray variety to appear white or yellow until one carefully examines the palea. Some varieties are heavily awned, while others are practically awnless and this aids in proper identification.

Most of the oats that are classed as black oats are in reality a dark red or brown, although a few varieties of little importance carry a dis-

tinct black color. Very few black oats are now grown commercially in America.

Agronomic Classification.—As farmers grow oats they are classed as spring and winter according to the season of the year in which the crop is seeded. While this grouping might be considered botanical, it appears more appropriate to class it as agronomic since it relates to production practices.

Fall or winter oats are limited to those sections where the winters are mild. Generally they are not grown north of a line extending east and west from central Missouri, although the belt extends somewhat farther north along the Atlantic and Pacific coasts.

Spring-sown oats are by far the most important, being grown both in the North and South. The leading oat-producing states are in the north where the winters are severe and spring-sown varieties are grown exclusively.

Market Classification.—On the market, oats are classed on the basis of the color of the lemma and palea of the matured grain. The five market classes are as follows:[1]

White oats
Red oats
Gray oats
Black oats
Mixed oats

In the designation of the market class, yellow varieties are classed as white. As the red-colored varieties do not always exhibit a distinct red color, the standards provide that "tinges of white, brown, or black, on the kernels of any red oats variety shall not affect their classification as red oats."

In addition there are standards for Feed Oats which are defined as

any grain which consists of either (a) 30 per cent or more but less than 80 per cent of cultivated and wild oats combined, or, (b) 80 per cent or more of cultivated oats and not more than 10 per cent of wild oats. Feed Oats may contain not more than 25 per cent of other grains, and may contain not more than 10 per cent of foreign material, which 10 per cent may include not more than 5 per cent of fine seeds.

A closely related market class is Mixed Feed Oats. The standards state:

[1] "Handbook of Official Grain Standards of the United States," *U.S. Dept. Agr. U.S.G.S.A. Form* 90, revised 1941.

Mixed Feed Oats shall be any grain which consists of less than 30 per cent of cultivated oats, but either (a) not less than 65 per cent of cultivated and wild oats combined or (b) not less than 65 per cent of wild oats; may contain not more than 25 per cent of other grains; and may contain not more than 10 per cent of foreign material, which 10 per cent may include not more than 5 per cent of fine seeds.

It is evident from the definitions of the two classes of feed oats that they represent grain which is of inferior quality for cereal purposes but may be used for livestock feeding.

The grades 1 to 4 and Sample Grade are based upon the weight per bushel, percentage of sound cultivated oats, damaged kernels, foreign material, and wild oats. Probably the most important factor is that of Sound Cultivated Oats, which is defined as "all kernels and pieces of kernels of cultivated oats which are not heat damaged, sprouted, frosted, badly ground damaged, badly weather damaged, or otherwise materially damaged." A careful consideration of this definition will indicate that the presence of other grains, as barley, will reduce the percentage of sound cultivated oats. Cultivated grains are not considered as foreign material but do affect the percentage of Sound Cultivated Oats.

Oats that are slightly weathered may not grade higher than No. 3. The weathered condition is one in which the caryopsis is discolored as a result of exposure to unfavorable weather conditions such as a period of rain on the grain while it is in the shock or windrow. When this condition is severe, the oats are considered to be materially weathered and may not be graded higher than No. 4. In many of the oat-producing areas the common summer showers frequently bring about the weathered conditions. With the greater use of the combine and the small threshing machine the problem of weathering is not as great, as oats are not required to stand in the field so long before threshing as was general a few years ago. Today some farmers stack their bundle grain, but the practice is not so common as it once was. The practice of windrowing oats when binder ripe before combining is increasing rapidly. Usually, after 2 or 3 days in the windrow the oats can be picked up and combined, thus largely removing the risk of damage by weathering before the grain becomes dead ripe.

USES OF OATS

Unlike wheat, oats are used primarily as a feed for livestock, although a considerable quantity each year enters into processed food products, particularly rolled oats. On an average, approximately 3 to 4 per cent of the annual production is used for human consumption. It is evident

that the amount of oats used for food is too small to affect the general market prices greatly. It is true, however, that in many seasons prior to the development of the new rust-resistant varieties the great processing plants sometimes found it very difficult to obtain a sufficient quantity of oats of the high quality to meet their needs.

The oat grain, in spite of its hull or covering, is fairly rich in protein and is considered a valuable feedstuff. For young growing or breeding animals, the oat is highly satisfactory. However, the hulls should be removed for young pigs, which should never be fed whole grain since the stomach of the pig may encounter difficulty in eliminating the high percentage of crude fiber that makes up the hull.

For many years, oats have been considered nearly ideal as a feed for horses and other work stock, and many farmers have used them. With the increased motorization of the farm, there has been a steady decline in the horse population, with a concurrent reduction in demands for oats as a horse feed.

The growing oat plant makes a very suitable temporary or emergency pasture crop, but it is not used for this purpose to any great extent, as generally rye proves more adaptable to a wider range of conditions. However, in some sections of the South, winter oats are extensively pastured, thus affording an incidental grazing crop of considerable importance. Some farmers do use the more mature plant for hay purposes, cutting the crop when the grain is in the milk or soft-dough stage. Such hay is very nutritious, and its palatability makes it the most popular of the cereal hays.

While oat straw is considered a by-product, it is of very great imimportance on the average farm where livestock is produced. Oat straw is fairly nutritious, and in an emergency a farmer may use it to advantage to supplement his short supplies of forage. However, most farmers do not depend upon oat straw for feed but do use it for bedding in their barns and lots where the absorbent qualities are of great value. The importance of straw has led many farmers to continue to use the binder and thresher rather than the combine, although some who use the combine gather the straw after it has been threshed.

A very economical and suitable type of shed for livestock may be constructed from a few posts, some wire, and a generous supply of straw. It is common to construct a framework and then direct the straw from the thresher to the emergency shed roof. Of course, other cereal straws may be used for the same purpose.

A common reason for growing oats in much of the country, especially in the corn belt, is because of its suitability in the crop-rotation scheme.

Not a few farmers follow a corn, oats, red clover rotation, In some cases it is a 2-year plan with the clover being plowed under in the fall of the year in which it was planted. Because of the ease with which the oat crop may be planted and managed, under a wide range of soil and climatic conditions, it is the most favored of the small grains grown in the corn belt. It is said that any farmer, regardless of how poor he is and how inadequate his equipment, can grow a fair crop of oats.

THE GROWING OF OATS

Although, as has been indicated, the oat crop may be grown successfully in spite of poor farming, this in no way implies that it is not profitable to use proper methods and to grow oats on suitable soils, correctly fertilized when necessary. Properly managed, the oat crop in view of limited labor requirements may prove profitable even as a cash crop. When the grain is used on the farm together with the straw, it is a very satisfactory crop and finds ready favor on the part of farmers in spite of generally better market prices for the other cereal grains. In a discussion of oat growing it is desirable to consider the problems by regions of the country since those of the South are quite different from those of the North.

Northern Oat Area.—The Northern states are by far the most important, not only in acreage but in total production of high-quality grain. The growing plant may be adversely affected by hot summer weather, especially at the time of flowering, and this is largely responsible for the better adaptation of oats to the North.

The oats of this area are almost universally spring-sown since the fall varieties will not survive the severe winters.

Varieties.—With the rapid development of better varieties, no list can be kept up to date, but some of the leading varieties grown in this region are Boone, Vicland, Tama, Cedar, Vikota, Control, Marion, Clinton, Ithacan, Wayne, Wolverine, Benton, Cornellian, Cartier, Columbia, and Rainbow. The first eight varieties named possess resistance to the rusts and smuts and are replacing even the few remaining older standard varieties mentioned here.

The newer disease-resistant varieties are doing much to stabilize production, since they reduce the dangers of crop failures. For several years, certain available varieties were more or less resistant to black stem rust, but it is comparatively recently that great progress has been made in breeding for resistance to crown rust. For the introduction of crown rust resistance, much use has been made of Victoria, an unadapted late-maturing type from South America, and Bond, a grayish-white oat

variety belonging to *A. byzantina*, introduced from Australia. It has been possible through the use of these introduced oats to develop new varieties from hybrids which have proved outstanding performers. Because of their greater resistance to certain diseases, particularly stem and crown rust and the smuts, and high yielding ability, certain of the new and improved varieties have largely replaced such old stand-bys as Albion (Iowa 103), Richland (Iowa 105), Gopher, Iowar, Nebraska No. 21, Cole, State Pride, Rainbow, Anthony, Upright, Wisconsin Wonder, Wolverine, and many others.

The hull-less varieties of oats have never been very popular and are generally grown on a very limited scale. Theoretically a hull-less oat should be ideal since it does not carry the hull, the factor that is the primary disadvantage of the oat as a feed. No varieties have been developed that will consistently yield as well as the better hulled types. Another disadvantage of the hull-less oat is the tendency of the threshed grain to pack closely, sometimes resulting in heating and damage if placed in large bins.

The principal hull-less varieties are Liberty, susceptible to the rusts and smuts, and Nakota, an improved variety developed by the South Dakota Agricultural Experiment Station. Nakota is fairly resistant to black stem rust and the smuts but is susceptible to crown rust.

Hull-less oats are managed much the same as the common oat with hulls. The weight per bushel is 48 lb., and the common seeding rate is 6 pecks per acre. Care must be taken in seeding to avoid the natural tendency of the seed to mass together in the drill box and not feed through at a uniform rate.

Culture.—General problems of oat culture were discussed in Chap. V. In most of the northern oat region, oats are seeded either with a grain drill or with a broadcast seeder. In Iowa, its center, it is common to seed oats on cornstalk land that has been disked to prepare the seedbed. In the East as in the New England states it is common to plow the land in preparation for oats.

In general, oats should never follow a legume in the rotation since the straw tends to lodge severely because of excess nitrogen. It is a general practice for oats to follow another small-grain crop or corn and to use the oats as a companion crop for the planting of small-seeded grasses and legumes.

Using well-cleaned seed, a rate of 8 pecks per acre is generally adequate when drilled, a 10- to 12-peck rate being more common when the seed is sown broadcast.

As is true for the other spring-sown grains, oats should be seeded

early to avoid the advent of warm weather at the time of flowering and subsequent filling. A few days' delay in seeding may result in a very sharp reduction in yield. Stanton and Coffman[1] in cooperative trials with the Iowa Agricultural Experiment Station found that deferred seeding, after the optimum date, decreased yields approximately 1 bushel per acre for each day of delay. Probably the primary advantage of the broadcast method is that it may permit earlier seeding than is possible with the grain drill, and it is a less expensive operation. Farmers who

FIG. 67.—Many acres of oats are seeded on corn-stalk land which is thoroughly disked to prepare the seedbed. (*Courtesy of the J. I. Case Company.*)

grow oats and corn in rotation are of the opinion that there is no justification for the purchase of the grain drill. With the increased culture of the soybean in the corn belt many have found it desirable to secure a grain drill, and it appears probable that more oats may be drilled in the future.

In areas where the corn borer is a menace, it is desirable to plow under the cornstalks as a measure of control. The Illinois station[2] has found that plowing usually increases oat yields by about 3 bu. per acre over those seeded on land that was not plowed.

Even though disease-resistant varieties are grown, it is desirable to

[1] STANTON, T. R., and F. A. COFFMAN, Grow Disease Resistant Oats, *U.S. Dept. Agr. Farmers' Bull.* 1941, 1943.

[2] DUNGAN, G. H., and O. T. BONNETT, Better Yields of Spring Oats with Better Varieties, *Ill. Agr. Expt. Sta. Circ.* 570, 1944.

treat the seed using New Improved Ceresan or similar compounds applied at the rate of ½ oz. per bushel, as outlined in Chap. VII. Not only will such treatment control the smuts, but it should aid in controlling many of the various soil-borne seedling diseases, which may reduce the stand appreciably.

Southern Oat Area.—As would be expected there is no sharp line between the northern and the southern areas. Along the East Coast, for example, the southern area extends far north, and there is an overlapping of the spring- and fall-sown oat districts. Stanton and Coffman[1] divide the southern oat region into two general areas: (1) the winter red oat area, coinciding closely with the cotton belt; and (2) the common winter oat area immediately to the north.

Varieties.—For many years the principal varieties grown in the South were red in color and representatives of *A. byzantina*. Important varieties included Red Rustproof, Fulghum, Burt, and others. The farmers of the South did not prefer a red oat to a white or yellow one, but it was found that the red oat is better adapted to the warmer climate and more resistant to or tolerant of the diseases of the region. The introduction of varieties such as Victoria and Bond in the breeding program has led to the development of very greatly improved varieties. Some of the leading southern varieties are Camellia, Fulgrain (strains 4, 5, 6, and 7), Fultex, Quincy Red, Quincy Gray, Ranger, Rustler, and Victorgrain red oats. Of the winter types, valuable varieties include DeSoto, Lega, Lelina, Letoria, Stanton, and Wintok. A complete discussion of the breeding of disease-resistant oats has been prepared by Murphy, Stanton, and Coffman.[2]

Forkedeer, Fulwin, and Tennex are selections from the Fulghum winter type which, though not disease resistant, have proved valuable because of their winter hardiness and suitability to the northern areas of the fall-sown oat region.

The winter oat has a definite place in the South, providing grain, hay, winter cover, and pasture. The fall-sown varieties where adapted usually greatly outyield spring-sown types, so that they are very popular. They have an added value of aiding in the control of erosion, a serious problem in much of the South. The earlier removal of winter oats makes it possible to plant succeeding crops earlier, a factor of considerable importance.

[1] Stanton, T. R., and F. A. Coffman, Disease-resistant and Hardy Oats for the South, *U.S. Dept. Agr. Farmers' Bull.* 1947, 1943.

[2] Murphy, H. C., T. R. Stanton, and F. A. Coffman, Breeding for Disease Resistance in Oats, *J. Am. Soc. Agron.*, **34**: 72–89, 1942.

Culture.—Fall-sown oats should be seeded with a drill on a well-prepared seedbed. It is common to seed them after a row crop that makes it possible to prepare a seedbed by disking and harrowing. In some cases the farmer seeds the oats between the rows of cotton, using the small five-hoe or disk drill. A firm seedbed is believed to be of special value in preventing heaving of the plants from the soil during the winter.

FIG. 68.—Harvesting oats with a combine. Crop seeded on the contour. (*Courtesy of the Allis-Chalmers Manufacturing Co.*)

It is advisable to treat soil for fall oats with liberal applications of commercial fertilizers in most areas. Stanton and Coffman recommend 200 to 300 lb. of superphosphate at the time of seeding, followed by a top dressing in February or early March of 100 to 150 lb. of sodium nitrate or 50 to 75 lb. of ammonium nitrate. If available, a light winter top dressing of well-decayed manure may be substituted for the nitrogen fertilizer.

Early seeding is advisable both for winter and spring types. In the northern half of the winter oat belt, winter oats should be planted 3 to 4 weeks before the average date of the first killing frost. In most of the cotton belt, best results are usually obtained by planting not later than the last week of October.

Rates of seeding are heavier for winter oats, to insure a satisfactory stand in the spring in areas where winterkilling may occur. The rates in the more hazardous sections range from 8 to 10 pecks per acre, while in the milder sections 6 to 8 pecks are usually ample.

As in the North, treatment of the seed with New Improved Ceresan will do much to control the numerous seedling diseases, rots, and blights that attack the oat plant.

For hay, oats should be cut not later than when the kernels are in the milk to soft-dough stage, as this results in the most palatable feed. For binder harvest the grain should be in the hard-dough stage. Where large acreages are grown for grain, it is desirable to begin harvest a little early to avoid overripeness of a part of the field with subsequent lodging. Where the windrower is used for combining, harvest is initiated at the same time as for the binder. If combined directly from the standing grain, it is necessary that the seeds be very hard. In most sections of the oat-growing areas it is impractical to leave the crop until it is mature enough to permit direct combining. Shock grain is threshed directly from the field or stacked for later threshing much the same as is done with other small grains.

OATS WITH OTHER CROPS

In many sections it is a common practice to grow oats and barley in a succotash mixture. The farmers who follow this practice believe that there are certain advantages of having a mixed feed for their livestock. Experimental trials have shown no advantage of the mixtures over growing the crops alone. A common mixture is to seed 1 bu. of oats with 1 bu. of barley. Oats may be combined with spring wheat or other spring grains, but the practice is not common. Where mixtures are used, it is desirable to choose varieties of the grains that ripen at approximately the same time.

Very excellent hay may be obtained in adapted areas from a combination of 1 bu. of field peas with 4 to 6 pecks of oats. The principal disadvantage of this combination is the relatively high cost of the field peas.

Review Questions

1. Cost records often show that oats do not pay, yet farmers grow many acres. Explain.
2. Name the species of oats grown in your area.
3. How can one recognize red oats?
4. What are the characteristics of the kernel of the wild oat?
5. Name the market classes of oats.
6. What are Feed Oats?

7. How are yellow glume oats classed on the market?
8. What is a weathered oat?
9. How suitable is the oat for feeding to livestock?
10. About what percentage of hull does the average oat have?
11. Why do properly harvested oats make such good hay?
12. How does the oat fit into the rotation?
13. What states lead in oat production?
14. Why does Iowa grow so many oats?
15. Why are northern-grown oats usually of superior quality?
16. Why is not the hull-less oat more popular?
17. Why should oats be planted early?
18. What types of oats are grown in the South?
19. What varieties have been used in the breeding of disease-resistant oats?
20. When should oats be harvested for hay?

References

CARLETON, M. A.: "The Small Grains," The Macmillan Company, New York, 1924.

DUNGAN, G. H., O. T. BONNETT, and W. L. BURLISON: Spring Oat Varieties for Illinois, *Ill. Agr. Expt. Sta. Bull.* 481, 1942.

HAYES, H. K., H. K. WILSON, and R. F. CRIM: Oats in Minnesota, *Minn. Agr. Expt. Sta. Special Bull.* 165, revised 1935.

HILL, D. D.: Oats Production in Western Oregon, *Ore. Agr. Expt. Sta. Bull.* 285, 1931.

KIESSELBACH, T. A., O. J. WEBSTER, and K. S. QUISENBERRY: Varieties of Oats, Barley, and Spring Wheat in Nebraska, *Neb. Agr. Expt. Sta. Bull.* 328, 1940.

MURPHY, H. C., and T. R. STANTON: Oat Varieties Highly Resistant to Crown Rust, *J. Am. Soc. Agron.*, **22**:573–574, 1930.

POEHLMAN, J. M.: Growing Good Crops of Oats in Missouri, *Mo. Agr. Expt. Sta. Bull.* 439, 1942.

QUISENBERRY, K. S., O. J. WEBSTER, and T. A. KIESSELBACH: Varieties of Oats for Nebraska, *Neb. Agr. Expt. Sta. Bull.* 375, 1945.

SCHLEHUBER, A. M., J. J. STURM, and R. H. BAMBERG: Oat Variety Tests in Montana, *Mont. Agr. Expt. Sta. Bull.* 399, 1942.

SHANDS, H. L., and B. D. LEITH: Vicland Oats, *Wis. Agr. Expt. Sta. Bull.* 462, 1944.

STANTON, T. R., and F. A. COFFMAN: Oats in the Western Half of the United States, *U.S. Dept. Agr. Farmers' Bull.* 1611, 1929.

———, and ———: Fall-sown Oat Production, *U.S. Dept. Agr. Farmers' Bull.* 1640, 1930.

———, and ———: Oats in the North Central States, *U.S. Dept. Agr. Farmers' Bull.* 1581, revised 1930.

———, and ———: Oats in the Northeastern States, *U.S. Dept. Agr. Farmers' Bull.* 1659, 1936.

———, and ———: Grow Disease Resistant Oats, *U.S. Dept. Agr. Farmers' Bull.* 1941, 1943.

———, and H. C. MURPHY: Oat Varieties Highly Resistant to Crown Rust and Their Probable Agronomic Value, *J. Am. Soc. Agron.*, **25**:674–683, 1933.

TINGEY, D. C., R. W. WOODWARD, and T. R. STANTON: Uton, A New High-yielding White Oat Resistant to Loose and Covered Smuts, *Utah Agr. Expt. Sta. Bull.* 296, 1941.

CHAPTER XI

BARLEY

Although barley is one of the world's oldest grain crops, having been used since Biblical times for food and feed, it is not nearly so widely grown as oats. Neither does the barley plant lend itself to the wide variety of uses of the oat, and in general it is grown as a more specialized crop in those regions to which it is adapted. Harlan and Martini[1] state that barley is a grain crop of many peoples throughout the temperate world and that it is man's most dependable cereal where alkali, frost, or drought occur. There are some who might question whether the barley plant is more adaptable to a wide range of conditions than the oat.

Much of the barley grown in America is used for livestock feed, with about 20 to 25 per cent being used for malt to enter into the production of beverages or foods.

BOTANICAL CLASSIFICATION

Barley is a member of the Gramineae family and the genus *Hordeum*. The cultivated varieties of barley all have seven paris of chromosomes. They have been classified by Harlan[2] as follows:

All spikelets fertile (6-rowed barley):
- Lemmas of all florets awned or hooded, *Hordeum vulgare* L.
- Lemmas of lateral florets bearing neither awns nor hoods, *H. intermedium* Kcke.

Only the central spikelets fertile (2-rowed barley):
- Lateral spikelets consisting of outer glumes, lemma, palea, rachilla and usually rudiments of the sexual organs, *H. distichon* L.
- Lateral spikelets reduced, usually to only the outer glumes and rachilla, more than one flowering glume present, and never rudiments of sexual organs, *H. deficiens* Steud.

[1] Harlan, H. V., and M. L. Martini, Problems and Results in Barley Breeding, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

[2] Harlan, H. V., The Identification of Varieties of Barley, *U.S. Dept. Agr. Bull.* 662, 1918.

According to Hayes and Immer,[1] the *H. intermedium* group should be described as central spikelets fertile, lateral spikelets partially fertile.

It should be noted that under the above classification the hull-less types are not considered as separate species. For example, varieties of hulled and hull-less barley are classified alike according to their floral arrangement.

FIG. 69.—Spikes of the principal types of barley, (*A*) six-row, (*B*) two-row, and (*C*) hooded. (*Courtesy of G. A. Wiebe, U.S. Department of Agriculture.*)

Most of the barley grown in America is of the six-row type. American malsters prefer the six-row over the two-row, and most barley breeders have devoted their energies to the improvement of the six-row varieties.

The hooded varieties in which the awn point is replaced with a hood-like appendage are grown to but a limited extent as they generally give low yields.

The *intermedium* type is of little economic importance, having failed to yield as well as the other common varieties.

[1] HAYES, H. K., and F. R. IMMER, "Methods of Plant Breeding," McGraw-Hill Book Company, Inc., New York, 1942.

AGRONOMIC CLASSIFICATION

Like oats, barleys are classed as spring and winter types. The winter varieties are much more hardy than winter oats and are grown considerably farther to the north.

By far the greater production is of spring barleys, as the leading states are to be found in the North Central states and California. Much of the winter barley is used as a cover crop and for pasture.

MARKET CLASSIFICATION

Barley grades under the supervision of the United States Department of Agriculture include four classes: Barley, Black Barley, Western Barley, and Mixed Barley.

Barley.—Most of the barley marketed comes in the class Barley. The standards define this class as all-white (glumes) barley grown east of the Rocky Mountains that does not contain more than 10 per cent of barley of other classes. Within the class Barley are two subclasses:

Malting barley
Barley

Malting barley includes:

> . . . 6-rowed barley of the class Barley which meets the requirements of grades Nos. 1 to 3, inclusive, which after the removal of dockage contains not more than 5 per cent of 2-rowed and/or other types or varieties of barley of unsuitable malting type such as Trebi and Black; which contains not more than 15 per cent of barley and other matter that will pass through a 20-gage metal seive with slotted perforations 0.076 (4⅞/64) of an inch wide and ¾ of an inch long; which contains not more than 4 per cent of damaged barley; and shall not include Bleached Barley. Barley of this sub-class shall contain 75 per cent or more of mellow barley kernels which kernels are not, en masse, semi-steely.

This statement means that to grade *malting* the barley must be of a six-rowed variety, not have more than 15 per cent of undersized kernels, be relatively free of broken or peeled kernels, and be relatively free of damage. Since the malting barley must germinate well to give a good yield of malt, the requirements are set up to ensure good germination. The requirement that the grain be mellow is for the purpose of securing starchy, not flinty, grain since these modify more easily in malting and yield a greater quantity of high-quality malt.

Naturally, varieties of barley will differ as to their suitability to qualify for malting, but here the effect of the environment may exert a marked influence. As a general rule the areas that produce a high-

protein wheat, such as the Dakotas, tend also to produce a flinty high-protein barley that is not favored by the maltster. Any barley of the class Barley that fails to grade in the subclass Malting falls in the subclass Barley.

Black Barley.—This class includes all varieties of black (glumes) barley regardless of where they are grown, whether two-rowed or six-rowed, and may not include more than 10 per cent of barley of other classes. There are no subclasses of black barley. Black barley is not an important class as compared with the class Barley, with little or none being grown in the United States.

Western Barley.—The class includes all white (glumes) barley grown west of the Great Plains area and may not include more than 10 per cent of barley of other classes. The greater part of the barley in this class is grown in California, and in normal times much of it is sold for export, chiefly to England.

Mixed Barley.—Any mixture of the different classes of barley falls in this grouping. The standards require that such barley shall be graded according to the grade requirements of (1) the subclass Barley of the class Barley, (2) the class Black Barley, or (3) the class Western Barley, according to which class of barley predominates in the mixture.

For each of the classes of barley, there are numerical grades of Nos. 1 to 5 and Sample Grade based upon the weight per bushel, damaged grain, foreign material, and broken kernels.

Several special grade designations are employed to indicate lack of quality, such as blighted, smutty, garlicky, ergoty, and weevily according to the factor that may operate.

IDENTIFICATION OF TYPES AND VARIETIES

The problems of varietal identification of barley are not quite so great as those with oats since some of the differences are more pronounced. Based upon the classification given, it is relatively simple to recognize the different species as determined by their floral characters. To separate the types after threshing is not so simple.

Two-rowed and six-rowed barleys must be recognized by the grain grader. In a given lot of six-rowed barley, approximately two-thirds of the grains will be slightly twisted while one-third will be rather uniform and straight. The grains from the middle spikelets are larger than those from the lateral spikelets.

In commerce it is necessary to be able to detect two-rowed barley which may be admixed with the six-rowed. The central kernels or grains of the six-rowed varieties are broadest near the tip, while those of the

two-rowed varieties are broadest near the base of the grain. Also the two-rowed barleys are boat-shaped when laid flat with the ventral side of the grain down, while the ventral side of the central grain of six-rowed barley often tends to be more flat.

The hull-less barleys look alike when threshed and can be recognized only by differences in color, ranging from white to a deep purple blue or black.

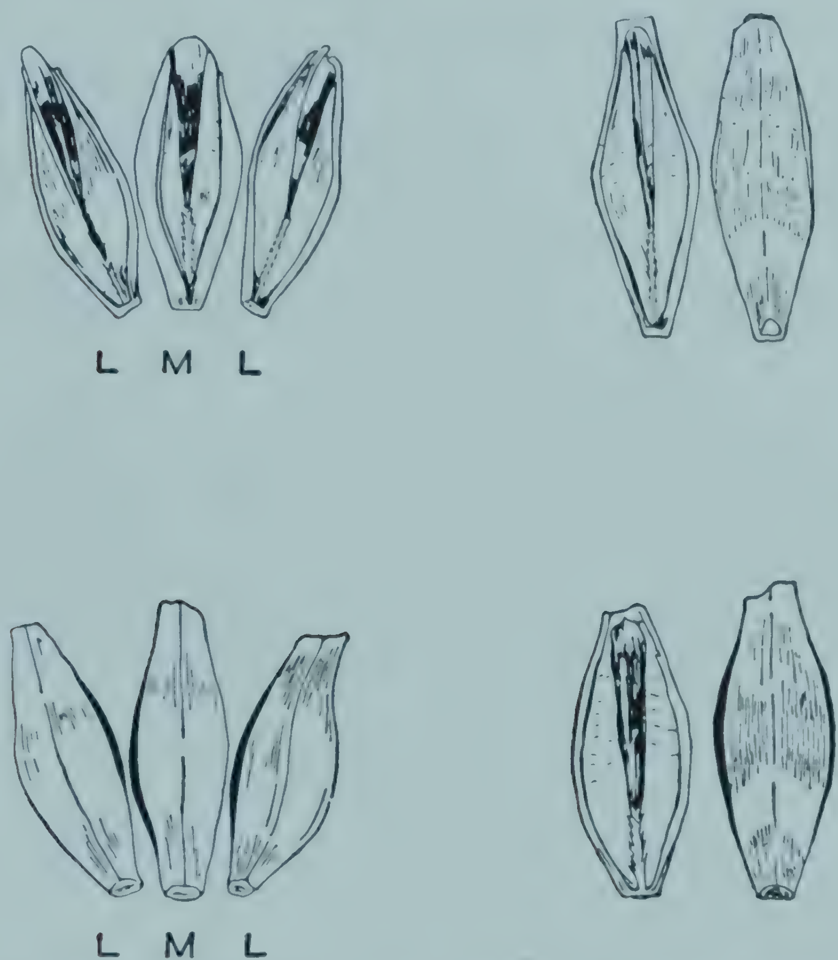


FIG. 70.—Front and back views of left, six-row barley; right, two-row barley, *L* refers to lateral florets, *M* to middle florets. (*Courtesy of the U.S. Department of Agriculture.*)

The development of smooth-awn types has created new problems in identification. If a few awns are present in the threshed grain one can readily determine whether the variety is smooth- or rough-awned.

The rachilla at the base of the spikelet has been used in varietal identification. As a rule the prevailing smooth-awn varieties have a long-haired rachilla, while that of rough-awn varieties is often short-haired. For example, Barbless (Wis. 38) has a long-haired rachilla, while that of Manchuria is short-haired. The use of these characters is pos-

sible after one has made a careful study of the varieties and has become thoroughly familiar with the differences.

Wiggans[1] has used several other characters for varietal separation, such as the variation in the barbing of the lateral nerves on the lemma and in the shape of the lemma base.

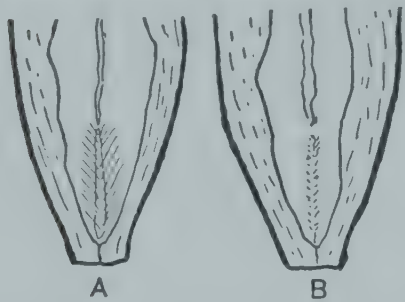


FIG. 71.—Characteristics of the rachilla of barley kernels. (*A*) long-haired rachilla and (*B*) short-haired rachilla. (*Adapted from Wiggans.*)

The caryopses of certain varieties of so-called white barley tend to be blue in color, while others are white. The variety Trebi, for example, is bluish in color, and since Trebi is undesirable for malting, its recognition is important. The blue color is due to a blue aleurone layer that occurs just below the seed coat.

A list of some of the varieties of barley of more or less importance is of interest.

SPRING BARLEY VARIETIES

Six-rowed Smooth-awned
- Arivat
- Barbless (Wis. 38)
- Bay
- Beecher
- Flynn 1
- Flynn 37
- Glacier
- Hero
- Lico
- Mars
- Plush
- Regal
- Rojo
- Tregal
- Vaughn
- Velvet
- Velvon

Two-rowed Smooth-awned
- Compana
- Spartan
- White Smyrna

Six-rowed Rough-awned
- Atlas
- Beldi Giant
- Blue
- California Mariout
- Club Mariout
- Coast
- Kindred
- Manchuria
- O.A.C. 21
- Oderbrucker
- Odessa
- Peatland
- Trebi
- Tunis

Six-rowed Hooded
- Colsess
- Horsford
- Meloy 3
- Union Beardless

Two-rowed, Rough-awned
- Alpha
- Hanna
- Hannchen
- Horn

[1] WIGGANS, R. G., A Classification of the Cultivated Varieties of Barley, *Cornell Univ. Agr. Expt. Sta. Mem.* 46, 1921.

WINTER BARLEY VARIETIES

Six-rowed Smooth-awned

- Jackson
- Marnobarb
- Nassau
- Texan

Six-rowed Hooded

- Iredell
- Missouri Early Beardless
- Tennessee

Six-rowed Rough-awned

- Kentucky
- Michigan Winter
- Olympia
- Purdue 21
- Reno
- Sunrise
- Tennessee Winter
- Ward
- Winter Club
- Wong

SEMIWINTER BARLEY VARIETIES
(Grown where winters are not severe)

- Davidson
- Ferguson
- Finley
- Randolph
- Tenkow
- Texan
- Wintex

Love and Craig[1] report that in tests of several varieties of winter barley in comparison with the spring-sown types at the Cornell Station the winter varieties proved superior in yield. They indicate that winter varieties can be expected to be superior only when winter-hardy varieties are grown. The winter variety Wong, a six-rowed stiff straw variety, proved to be superior to other varieties with which it was compared. Wong is highly resistant to mildew, a disease that does serious damage to barley under New York conditions, particularly in a cool growing season when moisture supplies are abundant.

It is advisable for every student to become familiar with those varieties that are recommended by his own state agricultural experiment station. Only in this manner can he keep abreast of the rapid changes made as new and superior varieties are developed by the plant breeder.

USES OF BARLEY

By far the greater part of the barley crop is used as feed for livestock. Barley assumes its greatest importance as a feed crop in those areas where it can be grown to better advantage than corn. On the whole it is very similar to corn as a feed, and according to Immer *et al.*,[2]

[1] LOVE, H. H., and W. T. CRAIG, Wong, a Winter Barley for New York, *Cornell Univ. Agr. Expt. Sta. Bull.* 796, 1943.

[2] IMMER, F. R., J. J. CHRISTENSEN, R. O. BRIDGFORD, and R. F. CRIM, Barley in Minnesota, *Minn. Agr. Ext. Special Bull.* 135, revised 1935.

for pork production, plump, full, weight-ground barley is about 95 per cent as valuable as shelled corn. On an average, barley has about 13 per cent hull, which is largely fiber and of little value for feed.

It is usually used for the feeding of hogs or cattle but is satisfactory for other classes of livestock.

Wilson and Wright[1] reported that in hog-feeding trials ground barley had a feeding value of 93.3 per cent of that of shelled corn. In the feeding of two-year-old steers it required on an average about one-eighth more barley than corn to produce equal results.

Peters[2] in Minnesota experiments obtained very satisfactory results in the feeding of whole barley to fattening lambs, but in feeding cattle found that better results were obtained when the barley was ground.

Crushing or coarse grinding is desirable when barley is fed to cattle. The gains more than offset the added cost of grinding. In the West it is common to roll the barley, using a jet of steam to prevent loss of material from shattering. Care should be taken to avoid grinding the material finely, so that when the animal eats, the feed will not be sticky and unpalatable.

Harlan and Wiebe[3] state that barley is especially valuable as a hog feed, producing firm pork. They believe that barley weighing 48 lb. per bushel has about the same feeding value as corn but that lightweight grain is decidedly inferior. Ordinarily, hogs will not eat scabby barley, but if they are forced to eat it they sicken and may die from poisoning if feeding is continued.

Barley makes a very satisfactory companion crop and in the rotation it frequently precedes a meadow or pasture seeding. The hay is not so satisfactory as oats but is used in some areas. Where grown for hay it is preferable to use hooded or smooth-awned varieties.

Harlan and Wiebe estimate that about 20 to 25 per cent of the average barley crop grown in the United States is used for malting. The requirements for superior malting barley are such that frequently a substantial premium is paid for malting barley. Varieties differ as to their suitability for malting, and to produce a satisfactory product it is necessary to start with a variety that is known to be suitable. Even when a desirable variety is used much depends upon the environment. The rela-

[1] WILSON, J. W., and T. WRIGHT, Barley as a Fattening Feed for Cattle and Swine in South Dakota, *S. D. Agr. Expt. Sta. Bull.* 262, 1931.

[2] PETERS, W. H., Grinding Shelled Corn, Barley, and Alfalfa Hay, *Minn. Agr. Expt. Sta. Bull.* 274, 1938.

[3] HARLAN, H. V., and G. A. WIEBE, Growing Barley for Malt and Feed, *U.S. Dept. Agr. Farmers' Bull.* 1732, revised 1943.

tively high humidity and fertile soils of southeastern Minnesota and southwestern Wisconsin usually produce a barley of malting quality. In a relatively dry area, such as the North Dakota wheat country, it is very unlikely that a mellow type of barley such as is desired by the trade will be produced except in an occasional favorable season.

Barley malt and its uses have been treated by Prescott and Proctor.[1] The principal uses are for the brewing and distillery industry with much of it entering into the manufacture of beer, whisky, and alcohol; for breakfast foods; for malt sirups used in baking, confections, and medicines; and as a desizing agent in the textile industry.

In the production of barley malt, the grain is carefully graded to remove all broken and small-sized kernels. As indicated earlier, barley that is badly skinned or broken cannot grade as malting since such injuries are certain to reduce the percentage of germination and subsequent quality of the malt. Next the cleaned barley is soaked in cool water for 30 to 72 hr. or until it reaches a moisture content of about 44 to 46 per cent. Following the steeping process the swollen grains are conveyed to germinating chambers, which are slowly revolving drums or compartments provided with stirring devices, maintained at a constant temperature and high humidity for a period of about 4 days. The barley germinates with the development of the radicle and the acrospire or plumule which force their way along under the barley hulls. During the process of germination the enzymatic systems are developed for converting the starch and proteins of the grain to fermentable substances. The maltster gauges the period of germination by the development of the acrospire. Usually by the time the acrospire emerges at the tip of the grain the process has proceeded to the desired stage. At this point, it is arrested from going farther by drying the grain in a kiln to a moisture content of 4 to 5 per cent. It requires about 2 days to reduce the moisture to approximately 5 per cent, after which the malt is separated from the sprouts and is ready for use by industry. A sound grain with a firm seed coat permits this process to proceed uniformly, while a broken or skinned kernel will permit the acrospire to emerge before the process of change has been completed.

The by-products of the malting process known as *brewers' grains* are utilized for livestock feed and are considered to be very valuable.

Other uses of barley as a food are limited. Some barley is pearled, *i.e.*, the hull and bran are removed by mechanical abrasion, and the caryopses are often used in soups. A very small percentage of barley

[1] Prescott, Samuel C., and Bernard E. Proctor, "Food Technology," McGraw-Hill Book Company, Inc., 1937.

is made into flours and meals which are used for the feeding of invalids and babies.

CULTURE OF SPRING BARLEY

Usually the average farmer places his barley on a somewhat better field or gives it a better place in the rotation than is the case with oats. It is safe to state that barley is more exacting in its soil requirements

Fig. 72.—Where barley follows corn, it is important to plow the cornstalks under thoroughly. (*Courtesy of the International Harvester Co.*)

and management than oats, and these probably are the principal reasons for using the more fertile soil for barley than for oats.

Soils.—The well-drained loams give the best yields of barley. Wet, poorly drained soils or areas that are sandy are likely to give poor results and will usually lead to greater returns if seeded to rye or oats.

Seeding.—The crop is normally seeded with a grain drill on a seedbed that has been well prepared. If barley follows corn it is important that the cornstalks be turned under thoroughly to aid in the control of scab (*Gibberella saubinettii*). The seeding of barley on disked cornstalk land may result in a serious scab epidemic in certain areas such as the corn belt. Where the disease is likely to be prevalent it probably is best to avoid following corn with barley.

To aid in the control of all diseases it is well to grow resistant varieties as recommended by the state agricultural experiment station. Barley stripe, covered smut, and some of the seedling blights may be

controlled through the use of New Improved Ceresan, as outlined in Chap. VII.

Early seeding is desirable, and a good rule is to seed about as early as the land can be prepared. Higher yields usually result from the earlier plantings, and there is less danger from seedling blights at the lower temperatures of early spring. The rates of seeding vary in different sections but usually range from 6 to 10 pecks in the humid areas, with lighter rates in dry-land areas. An excellent discussion of rates for each of the states is given by Harlan and Wiebe.[1] If clean seed of high quality is seeded on a well-prepared seedbed one may reduce seeding rates somewhat from the average.

Harvesting.—It is desirable to permit barley to become well matured before harvest, since premature harvesting results in lower weight grain, shriveled steely kernels, and reduced yields. This is especially important with malting barley since a large well-developed grain is more likely to germinate well and yield a good quantity of malt.

Usually somewhat better quality malting barley is obtained if the grain is harvested with a binder and cured in well-capped shocks or in stacks made of the bundles. In an area subject to frequent summer rains, it may be advisable to stack the grain if threshing is to be delayed. If the barley is to be used for feed, then extra care is not so essential and the combine may be used to advantage. Of course, in irrigated or dry-land areas the combine may be used even for harvesting malting barley.

Certain smooth-awned barleys seem to have a more loosely attached hull than the old rough-bearded types. For this reason they skin more easily, and greater care must be taken in their threshing. It is well to check the threshing machine carefully to make certain that the cylinder is in proper adjustment and that every means is taken to ensure a good job of threshing. A little care at the time of threshing may make a big difference in the price received if the grain is to be marketed.

CULTURE OF WINTER BARLEY

Winter barley is more hardy than winter oats and therefore is grown farther to the North. As shown earlier most of the crop is grown in southeastern United States, where the farmers grow it for grain, as a cover crop, and for fall and spring pasture.

Seedings are made from late September to the middle of October in most areas, although the period may be extended considerably in some

[1] HARLAN, H. V., and G. A. WIEBE, Growing Barley for Malt and Feed, *U.S. Dept. Agr. Farmers' Bull.* 1732, revised 1943.

sections. In California, spring barley plantings are made as late as the middle of January, but where the crop is to be pastured, earlier seedings are advisable. In New York, where a limited acreage of winter barley is grown, it is common to seed about the middle of September.

Winter barley may be planted either with a grain drill or seeded broadcast. Rates vary from 4 pecks in the drier sections to 10 pecks

FIG. 73.—Many small threshing outfits are used. These make it possible to preserve the straw so valuable for bedding. (*Courtesy of the J. I. Case Company.*)

where rainfall is heavier. On an average, about 8 pecks to the acre is the most common rate.

Atkins and Dunkle[1] report that in central Texas the barley seedbed is often prepared by disking or by harrowing to level the ground following a crop of cotton. Corn or small grain land that is to be seeded to winter barley should be plowed as soon as possible and kept free of weeds until planting time.

Winter barley is harvested much the same as spring barley. As it is rarely used for malting it is not so necessary to exercise care in producing bright sound grain, since most of the grain is used for livestock feeding. Where it is used for both pasture and grain it is advisable to

[1] ATKINS, I. M., and P. B. DUNKLE, Barley Production in Texas, *Tex. Agr. Expt. Sta. Bull.* 605, 1941.

avoid too heavy or late grazing as this is certain to reduce the yield of grain seriously.

Review Questions

1. What are the principal uses of barley?
2. How does malting barley differ from feed barley?
3. How does barley compare with corn as a feed crop?
4. Explain the morphological differences between two-rowed and six-rowed barley.
5. Where are winter barley varieties grown?
6. Why is not more two-rowed barley grown in this country?
7. What is Western Barley?
8. How can one differentiate between the kernels of two-rowed and six-rowed barleys?
9. About what percentage of hull does the average barley grain possess?
10. Botanically, what flower parts constitute the hull of barley?
11. What are the limitations in the feeding of scabby barley?
12. What climatic conditions favor malting barley?
13. Enumerate the uses of malt.
14. Why is uniformity of germination so important in malting barley?
15. What are brewers' grains?
16. When should spring barley be planted?
17. How can we best hope to control barley diseases?
18. What are the advantages, if any, of stacking barley before threshing?
19. When should winter barley be planted?
20. What special precautions should be observed in threshing malting barley?

References

ABERG, EWERT, and G. A. WIEBE: Classification of Barley Varieties Grown in the United States and Canada in 1945, *U.S. Dept. Agr. Tech. Bull.* 907, 1946.

ATKINS, I. M., and P. B. DUNKLE: Barley Production in Texas, *Tex. Agr. Expt. Sta. Bull.* 605, 1941.

BURNETT, L. C., and C. S. REDDY: Barley in Iowa, *Iowa Agr. Expt. Sta. Bull.* 367, 1937.

CARLETON, M. A.: "The Small Grains," The Macmillan Company, New York, 1924.

DELONG, H. H.: Cylinder Adjustments for Threshing Barley, *S. D. Agr. Expt. Sta. Bull.* 377, 1944.

DUNGAN, G. H., and W. L. BURLISON: Spring Barley in Illinois, *Ill. Agr. Expt. Sta. Bull.* 485, 1942.

KIESSELBACH, T. A., O. J. WEBSTER, and K. S. QUISENBERRY: Varieties of Oats, Barley, and Spring Wheat in Nebraska, *Neb. Agr. Expt. Sta. Bull.* 328, 1940.

LEITH, B. D., H. L. SHANDS, and R. A. MOORE: Quality Barley—How to Grow—How to Handle, *Wis. Agr. Ext. Circ.* 278, 1936.

SWANSON, A. F., and H. H. LAUDE: Barley Production in Kansas, *Kans. Agr. Expt. Sta. Bull.* 318, 1943.

CHAPTER XII

FLAX

The flax plant has long been important in the life of man. It is known that the Egyptians grew flax at a very early period as they had developed the art of manufacturing high-quality linens. While flax was used to some extent as a food in early times, it did not assume great importance in this respect. In a few countries such as India and parts of Russia, flax is used for food purposes today. Seed flax in America is grown for its oil, which is used in the paint and related industries; the straw is being used increasingly for paper and other manufactured products. By far the most important by-product is linseed meal, a greatly prized feed for livestock.

FIG. 74.—A flax plant showing both flowers and seed bolls. (*Courtesy of the U.S. Department of Agriculture.*)

BOTANICAL CLASSIFICATION

Flax is a member of the flax or Linaceae family. The cultivated flax is classed as *Linum usitatissimum* L. The plant is an annual which ranges in height from about 1 to 3 ft. The five-petaled flowers vary in color from white to a deep blue. The normally self-pollinated plant produces five compartment bolls containing 10 seeds, very rich in oil and brown or yellow in color, with the brown seeded varieties most common.

Most flax in America is grown for its seed, but in some areas it is grown primarily for the strong fibers found in the stems. These are used in the manufacture of linens and related products.

Dillman[1] states that most investigators agree that *Linum usitatis-*

[1] DILLMAN, A. C., Improvement in Flax, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

simum has 15 pairs of chromosomes, although some workers have reported deviations from this number. Ray[1] concludes that without doubt the correct chromosomal number for flax is 15(N) and 30 (2N) or 15 pairs as indicated by Dillman.

AGRONOMIC CLASSIFICATION

The most common grouping of flax is based on the use made of the plant. The principal classes are seed flax and fiber flax. Almost all the flax grown in America is of the seed-flax type with some secondary use made of the fibers. The true fiber types are grown only on a limited acreage. These are primarily in the Pacific Northwest with an average acreage of 8,000 for the years 1936–1945 in the Willamette Valley.

As discussed in Chap. III, most of the seed flax is grown in but a few states, *viz.*, North and South Dakota, Minnesota, Montana, and California. In these states are found the conditions most favorable for the production of seed flax varieties.

The seeds of flax varieties may be brown or golden colored. Dillman and Stoa[2] list the following types of seed flax:

Wilt-resistant, short-fiber varieties
Common or so-called *Russian* types
Argentine varieties
Abyssinian
Indian
Golden or yellow-seeded
Others of little commercial importance

Most of the important varieties in America belong to the wilt-resistant short-fiber type. The wilt susceptibility of the common or Russian varieties has led to their near disappearance.

The Argentine varieties requiring a longer growing season have not proved suited to the North Central states but have done somewhat better in California, according to Dillman and Goar.[3]

The more desirable varieties of flax grown in America are moderately resistant to wilt and very resistant to flax rust; although many moderately rust-susceptible varieties are grown.

The Indian, Abyssinian, and Golden flaxes are usually short and have

[1] RAY, CHARLES, JR., Cytological Studies on the Flax Genus, Linum, *Am. J. Botany* **31**:241–248, 1944.

[2] DILLMAN, A. C., and T. E. STOA, Flax Seed Production in the North Central States, *U.S. Dept. Agr. Farmers' Bull.* 1747, revised 1942.

[3] DILLMAN, A. C., and GOAR, L. G., Flax Seed Production in the Far Western States, *U.S. Dept. Agr. Farmers' Bull.* 1893, 1937.

not found ready favor in the North Central states. Recently, certain Golden-seeded varieties, such as Crystal, have met with favor because of their superior oil quality. In California, Punjab, a selection from commercial seed introduced from India, has proved productive.

The Abyssinian varieties have fine-stemmed plants with blue flowers and small brown or yellow seeds.

The Golden flax varieties usually have pale pink to white flowers and yellow seeds commonly referred to as "Golden."

FIG. 75.—Flax variety plots, Montana Agricultural Experiment Station, Bozeman, Mont. (*Courtesy of A. C. Dillman, U.S. Department of Agriculture.*)

Varieties.—Much work is being done in the improvement of flax, primarily to secure higher yielding disease-resistant varieties whose seeds possess a high percentage of oil of superior drying qualities. No list of varieties as given in a textbook can be kept up to date, so it is important that the student become familiar with those varieties currently recommended by his own state agricultural experiment station. For the purpose of orienting the reader and partly for historical reasons, a few of the more important varieties are listed.

In the North Central states some of the varieties that have been important in the past, and those which are replacing the old varieties, include the following: Linota, Buda, Bison, Redwing, Biwing, Redson, Koto, Royal, Renew, Victory, and Arrow. Golden-seeded varieties include Viking, B. Golden, Crystal. It is to be expected that many changes will occur as improvement makes better varieties available.

Market Grades.—Because the flax plant is a poor competitor of

weedy plants, most of the seed that comes to market contains a high percentage of dockage. In a study by Cox and Brookins[1] 7,413 cars, or about 84 per cent of the total flaxseed marketed in Minnesota in one year, showed an average dockage of 11.3 per cent, or an equivalent of about 1 car of dockage for every 10 cars of clean flax. The percentage of dockage ranged from 3 to 37. Of the more than 13 million bushels marketed, more than 41,000 tons of dockage were received at the terminal markets during the crop season, using the space of 950 cars and costing in excess freight more than $138,000.

The official Grain Standards define flaxseed as any grain that, before the removal of dockage, consists of 50 per cent or more of flaxseed and not more than 20 per cent of other grains for which standards have been established under the provisions of the United States Grain Standards Act.

The standards include two numerical grades and Sample Grade, determined after the removal of the dockage. No. 1 flax must weigh at least 49 lb. per bushel and contain not more than 20 per cent damaged flaxseed. No. 2 flax must weigh at least 47 lb. per bushel and may not contain more than 30 per cent of damaged flaxseed. Flax that does not meet the requirements of No. 1 or No. 2 or that contains more than 11 per cent moisture, is heating, hot, musty, or sour, or otherwise of distinctly low quality, is placed in Sample Grade.

Doctor A. C. Dillman, associate agronomist formerly in charge of flax investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture in a personal letter to the author made the following statement relative to the marketing of flax:

> In actual practice at Minneapolis and also in California, linseed crushers buy flax on their estimate of the oil content and the iodine number; that is, they pick the carloads of flax from the areas where the best quality seed is produced. They determine this by analysis of samples obtained from the first threshed samples or from the first carloads that come on the market. The real value of flax seed is determined by the oil content and iodine number rather than on market grade. In California, for example, the dry flax seed of very high oil content will hardly test more than 49 or 50 pounds per bushel.

USES OF FLAX

As indicated in the discussion of classification, flax is grown for its seed and fiber. From the seed is obtained an oil that is desired by the paint and related industries.

[1] Cox, R. W., and W. W. Brookins, Dockage in Flax Seed, *Minn. Agr. Expt. Sta. Bull.* 371, 1943.

From the seed is manufactured linseed oil and its by-product, linseed meal, a protein-rich feed that is highly prized by feeders of livestock. The linseed oil is used in the manufacture of paints, varnishes, linoleum, oilcloth, printer's ink, patent leather, and other products of less importance. The seed may yield 32 to 44 per cent of oil based on dry weight. Dillman and Stoa state that in commercial crushing about 19 lb. or 2½ gal. of oil is obtained from a 56-lb. bushel of seed. The drying quality of the oil varies with varieties and with seasons. Quality is expressed as the "iodine number"; the higher the iodine number, the better the oil. The iodine number is determined by a chemical test to ascertain the drying quality of the oil, or the quantity of oxygen that the oil will absorb in drying to form the characteristic oil or paint film. Without this quality, paint would fail to dry and form the tough film that makes it so useful as a preservative.

The oil is pressed from the flaxseed by huge hydraulic presses. The residue known as *linseed cake* is dried and ground into a meal for sale to livestock feeders. Usually the seed is ground finely, then transferred to a steam-heated press which heats the meal to near the boiling point. The huge press then forces the oil from the meal. This extracts the oil except for some 3 to 6 per cent which cannot be extracted by ordinary means and usually remains in the meal as it is marketed. On an average the meal contains about 30 per cent of protein. The use of the hydraulic press is referred to as the *old-process* method of oil extraction.

A few years ago, the so-called *new-process* method of oil extraction was developed. This involved the use of naphtha to absorb the oil from the meal, a process that was very successful but because of the inflammable nature of naphtha has been generally discontinued.

Most of the oil mills are located near the center of flax production and on the two coasts, where both domestic and imported seed is crushed. The mills on the Atlantic Coast at Philadelphia, Edgewater, N. J., and near New York City crush much seed imported from Argentina. On the Pacific Coast, mills at Portland, Ore., and San Francisco and Los Angeles, Calif., crush both domestic and imported flax. In the interior, the largest mills are located at Minneapolis, Minn., with smaller units in near-by cities of the Middle West.

Fiber flax is grown to some extent (5,000 to 10,000 acres) in Oregon and does not represent a large industry. Here varieties especially suited to the manufacture of linen and related products have been developed. In general these varieties produce relatively little seed. Principal varieties of fiber flax are Cirrus, Saginaw, and Liral.

Fiber from the seed flaxes is of great importance. For many years,

a limited quantity of flax straw was used to manufacture such products as rugs and insulating wallboard, but it was not until the Second World War that the use of flax straw really became a big industry in America. Prior to the war, cigarette paper was made from linen rags obtained in Europe. With this source cut off, industry looking for other sources turned to flax straw. Today, nearly all the cigarette paper used in America comes from flax straw which is a by-product of the seed-flax industry.

CULTURE OF FLAX

By the nature of its growth and requirements, flax culture is rather specialized and is not nearly so simple as that of wheat, oats, and other small grain crops. The crop is a high-value one under favorable conditions because the country usually does not produce sufficient flax to meet its needs. As a rule, a high tariff is maintained to bolster the price, but in spite of this it has been difficult to maintain the needed production. Factors responsible for this situation will be considered in the discussion of flax culture.

Relative Value of Flax.—The flax crop as grown in America is a cash crop, and it is not fed on the farms as is common with most of the other grains. With an average yield in the United States of 9 to 10 bu. per acre and an average price in recent years of $2.50 to $3 per bushel, it is evident that flax is a good cash crop. Good farmers often secure yields of 15 to 20 bu. or more, and considering the relative costs of production flax rates very high. Hayes, in a comparison of flax with several other crops, showed flax to rank high as a cash crop.

Considering the figures shown in Table 35 on returns from flax, one naturally raises the question, why do not more farmers grow flax? Possibly the most important reasons are that there is more uncertainty with the flax crop than with a crop like oats and the fact that many farmers experience more difficulty with weeds in flax growing. However, with proper management the weedy plants can be controlled and much of the uncertainty in flax culture can be removed. It is true that for efficient production flax requires good management, and the farmer who practices it will usually find that it pays big dividends.

Rotation.—Since weeds constitute the principal menace to flax culture, the rotation should be such as to most nearly ensure the control of weedy plants. In early days, flax was seeded on new sod lands and the weed problem was not great. Today, with the great increase in weeds, these constitute genuine hazards. The best practice is to give flax the place in the rotation which offers the best opportunity for a

clean field. Many farmers seed flax after one year of corn or after a hay or pasture crop.

Brookins[1] recommends 2 years of cultivated crops in succession before flax is planted so as to provide better weed control. He believes that flax should be sown on either plowed or disked-cornstalk land that has been worked previously to stimulate the sprouting of weeds which may be destroyed before the flax is seeded.

TABLE 35.—FARM VALUE IN DOLLARS PER ACRE OF CROPS GROWN AT DIFFERENT LOCATIONS IN MINNESOTA, BASED ON AVERAGE YIELDS IN VARIETAL TRIALS AND NOV. 15 OR DEC. 1 MINNESOTA FARM PRICES*

Crop	Location of trial			
	University farm	Waseca	Morris	Crookston
Flax	$20.59	$32.58	$24.34	$23.09
Oats	17.40	21.33	17.49	17.55
Barley	19.92	24.43	18.19	17.04
Spring wheat	21.90	22.36	20.98	19.87
Durum wheat	21.54	24.74	22.25	21.63
Winter wheat	23.93	26.57		
Rye	18.73	21.29	16.53	
Corn	23.59	34.29	24.70	17.97
Soybeans	21.63	25.22	21.89	17.28

* Adapted from H. K. Hayes, Comparative Value of Flax and Other Farm Crops Grown under Comparable Conditions, "Flax Facts," 2d ed. revised, published by E. J. Mitchell, Flax Development Committee, Minneapolis, 1944.

In California, flax is usually seeded on fallowed land or following a clean-cultivated crop or a green manure crop plowed under. Alfalfa, clover, wheat, or barley land also is suitable to flax if weeds have not become a menace in the fields.

Dillman and Goar recommend that flax should not immediately follow the sorghums, Sudan grass, or millets, as these crops tend to exert deleterious effects upon the flax plant, since the soil is likely to be depleted of readily available nitrates.

Flax is an ideal companion crop for small-seeded legumes and grasses. Many farmers use the crop in this manner, as the flax provides but little competition to the growing seedlings. Naturally, the nature of the plant

[1] BROOKINS, W. W., "Weeds in Flax," published by Central Fiber Corp., Pisgah Forest, N. C., 1944.

which makes it a good companion crop leads to its being unsuccessful as a weed competitor.

Variety.—The variety should be one that is recommended by the state and Federal agricultural experiment stations. Usually these varieties are moderately resistant to the prevalent diseases, although susceptible varieties frequently produce well as a result of escaping disease.

Clean Seed.—Much of the difficulty with weeds in flax culture may be traced to the use of unclean seed. A little extra care and expense to obtain clean seed will save much labor later and may result in much better yields. The farmer who raises his own seed should take it to a seed-cleaning plant where equipment is available to do a thorough job. Seldom is the flax crop as it comes from the thresher clean enough to seed without additional processing.

Seedbed.—Methods are similar to those outlined in Chap. V. Extra care should be taken to destroy as many weeds as possible. Early plowing or disking, where erosion is not a problem, and shallow working the soil to stimulate the germination of weed seeds will do much to reduce competition the following year. The seedbed should be firm to favor rapid germination and quick growth of the flax plants.

Seeding.—Most flax is seeded in the spring and generally should be planted as early as possible. Dillman and Stoa state that after flax plants are 2 to 3 in. in height they will endure temperatures of 20 to 22°F. for a short time without injury. Delay in seeding usually results in lower yields. In most parts of California, Arizona, and Texas flax is seeded in the fall of the year. In the Southwest the best dates are from Oct. 20 to Nov. 20, although in Texas some varieties do best if seeded about Oct. 1.

Flax is seeded with a grain drill at rates that vary in different parts of the country. In southern Minnesota rates of 3 pecks per acre are common, while in the Dakotas and Montana 2 pecks are considered sufficient. In the West, 3 pecks are common on irrigated lands, with 2 pecks used on nonirrigated land in the drier sections. With the large-seeded varieties, rates are usually increased about one peck per acre.

Harvesting.—Flax is harvested much the same as other grains, with the use of the combine becoming more and more common. The windrower should be used ahead of the combine if the field is weedy.

In nearly every section it will pay the grower to reclean the flax before it is marketed. This may be done on the farm with a portable unit, or the flax may be hauled to a near-by elevator. Little flax is produced that will not benefit from such cleaning.

FLAX AND CEREAL MIXTURES

Arny *et al.*,[1] working at several stations in the flax-producing states, reported that flax and spring-sown cereals grown in combination aided in the control of weeds. Extensive trials over a period of several years showed an advantage in the control of many common annual weeds, but perennial weeds such as Canada thistle and quack grass were not checked. Various combinations of seeding have been used in the different states. A mixture of 42 lb. of flaxseed and 45 lb. of spring wheat per acre has been used successfully where it was desired to grow a mixture.

FIG. 76.—Harvesting a crop of flax with the combine. (*Courtesy of the U.S. Department of Agriculture.*)

The principal disadvantages of the combination of the crops are (1) that the seeds must be separated before marketing and (2) that the straw cannot be used by the industries. With the increased use of flax straw for its fiber, the latter objection has become of added importance. In general, relatively few farmers grow the two crops in combination.

FLAX STRAW

The development of a great paper industry using flax straw has made it possible for flax producers to market a crop that was of relatively little value as compared with other grain straws.

Since the price paid for flax straw depends upon the use that can be made of it, it is important that it be relatively free of weeds. Accord-

[1] ARNY, A. C., T. E. STOA, CLYDE MCKEE, and A. C. DILLMAN, Flax Cropping in Mixture with Wheat, Oats, and Barley, *U.S. Dept. Agr. Tech. Bull.* 133, 1929.

ingly, Brookins[1] states that flax straw reasonably free of weeds requires 5 tons of straw to produce 1 ton of tow for paper manufacture. Where weeds are abundant, 6 to 7 tons of the weed-infested straw may be required to produce 1 ton of tow.

Farmers who wish to market their straw doing their own baling should observe the following rules:

1. Bale only cleanest straw.
2. Throw out wet straw.
3. Avoid baling straw containing chaff.
4. Make 80-lb. bales.
5. Stack bales to ensure ventilation.
6. Cover bales to avoid damage from rain.
7. Build stacks to shed water.

Combined straw is often cleaner than that from bundle-threshed grain. This is especially true if the windrower is used.

Many farmers will find that the sale of such flax straw will add to their profits and it will pay them to produce the highest quality of straw, free from weeds and properly stored.

PESTS OF FLAX

The principal pests of the flax crops are weeds and diseases. Generally, the crop is not greatly troubled with insects except under conditions where an outbreak of some particular insect occurs.

Weeds.—The best control of annual weeds lies in prevention and the use of clean seed. Fields that are infested with broad-leaved annuals such as the mustards may be sprayed effectively with chemicals such as Sinox, as described in Chap. VI.

Diseases.—The principal diseases of flax were listed in Chap. VII. Wilt, rust, pasmo, and seedling blights may do much damage. Early seeding in a well-prepared seedbed with varieties of known disease resistance will do much to ensure disease control. Many farmers make it a regular practice to treat their flaxseed with an organic mercury dust, a practice that will do much to control certain seedling diseases which may do great damage to the crop.

Pasmo (*Phlyctaena linicola*) is one of the more recently introduced diseases of flax. It produces yellow-brown circular lesions on the cotyledons and foliage of the young flax plants. Later the plants show irregular bands of brown mottling alternating with bands of green. In severe cases the plants look much as though they had been seared in spots with a torch. The Argentine varieties are especially susceptible.

[1] Brookins, W. W., "Flax Straw Increases Crop Income," published by Central Fiber Corp., Pisgah Forest, N. C., 1942.

TABLE 36.—EFFECTS OF SEED TREATMENTS ON THE EMERGENCE OF FLAX PLANTS IN FIELD PLANTINGS*

Variety	Germination in blotters, per cent	Emergence of nontreated seed, per cent	Emergence from ethyl mercury phosphate (Ceresan), per cent	Seed treated with	
				Spergon, per cent	Arasan, per cent
Bison	97	83	84	80	83
Redwing	93	83	92	83	†
Redwing	85	64	80	71	†
B. Golden	84	67	75	71	72
Bison	62	46	57	57	58
Crystal	55	23	33	30	34
Viking	90	77	78	79	76
Mean	81	63	71	67	65

* Adapted from W. E. Brentzel, Studies on Seed Treatments for Cereal Crops, *N. D. Agr. Expt. Sta. Bull.* 331, 1944.

† Not treated with Arasan.

According to Flor and Christensen,[1] if pasmo strikes a crop approaching maturity the yields may be materially reduced. Earlier attacks may result in plant defoliation, blighted flowers, weakened stems, undeveloped bolls, and poorly developed seeds. In 1943, losses of 50 per cent or more were common in fields of Viking flax in parts of North Dakota.

Review Questions

1. Why is it wrong to refer to flax as a cereal?
2. Why did flax production move from the East to the West in the early history of our country?
3. What man first gave a method for solving the problems of flax wilt?
4. List the types of seed flax.
5. What is meant by a "drying oil"?
6. How is dockage related to weed control?
7. What is meant by iodine number?
8. Why is oil meal so highly prized by livestock feeders?
9. Where is fiber flax grown?
10. What use is made of flax straw?
11. Why do flax fields tend to become so weedy?
12. Outline a rotation including flax.
13. Why do not more farmers grow flax?
14. When should flax be planted?

[1] FLOR, H. H., and J. J. CHRISTENSEN, Diseases of Flax, "Flax Facts," 2d ed., revised, published by E. J. Mitchell, Flax Development Committee, Minneapolis, 1944.

15. At what rates should flax be seeded?
16. What place do flax-wheat mixtures have?
17. How do weeds affect the quality of flax straw?
18. What can one do to improve the market quality of straw?
19. What country is our chief competitor in flax production?

References

"Flax Facts," Encyclopedia of Information, 2d ed., revised, published by E. J. Mitchell, Flax Development Committee, Minneapolis, 1944.

HARRINGTON, J. B.: The Growing of Flax, *Univ. Sask. Agr. Ext. Bull.* 62, revised 1944.

HOPPER, T. H., and M. JOHNSON: Flax Production and Climate of North Dakota and Minnesota, *N. D. Agr. Expt. Sta. Bull.* 298, 1941.

KLAGES, K. H. W.: Flax Production in Idaho, *Idaho Agr. Expt. Sta. Bull.* 224, 1938.

POST, A. H., and S. C. LITZENBERGER: Flaxseed Production in Montana, *Mont. Agr. Expt. Sta. Bull.* 429, 1945.

SULLIVAN, WALLACE, H. L. LANDERMAN, and G. A. CARPENTER: Flax Management Practices in Imperial Valley, with World Statistics, *Calif. Agr. Expt. Sta. Bull.* 641, 1940.

CHAPTER XIII

RICE

When one thinks of rice he naturally tends to think of the Orient, where 95 per cent of the world's rice crop is produced. The average citizen does not realize that the United States produces more rice than is required for its possessions and home consumption and in normal times exports rice to Cuba, South America, and Europe. It is true that America's production is small compared with that of most Asiatic countries where rice is the principal article of food, but in parts of the South and Far West, the rice crops is of great value.

In the Orient many of the inhabitants consume an average of 200 to 400 lb. of rice each year. In the United States the average consumption is about 6 lb. per year. Thus it is evident that rice forms but a small part of the diet of the average American. In most cases it is eaten occasionally as a dessert or pudding, but in some sections, rice is a regular part of the diet like the potato or bread.

BOTANY OF RICE

Rice, a member of the grass family, is classified as *Oryza sativa* L. The plant is normally self-pollinated, although some natural crossing occurs.

According to Jones,[1] all cultivated varieties investigated had 12 pairs of chromosomes, a rather unusual condition when one considers the wide variation that exists among the different varieties as grown in various parts of the world.

The rice plant possesses many of the characteristics common to the other cereals. It differs principally in that it is grown on land that is submerged for 60 to 90 days or more during the growing season.

The rice kernel or fruit is starchy in nature, being a high-energy food. The protein is found in the bran layer and in the endosperm. In the removal of the hull and seed, in the preparation of the rice for consumption, much of the food value is lost. Where a varied diet is followed, the losses in the milling of rice are not so serious. To peoples who depend almost entirely upon rice, however, for their sustenance, the

[1] JONES, JENKIN W., Improvement in Rice, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

removal of many of the vitamins and minerals, essential nutritional adjuncts, through milling is very undesirable and may result in serious diseases of malnutrition among consumers on a restricted diet.

PROCESSING OF RICE

As rice is harvested, the kernel is enclosed by the hull and a tightly adhering seed coat. The hull must be removed before it is prepared for food. The threshed grain is passed through millstones which remove the hull so that it can be separated from the caryopses (kernels).

Rice with the hull removed is known as *brown rice*. The bran layers are removed by passing the brown rice through hullers which grind away the thin outer covering and germ. After the removal of the bran, the rice is rough and is referred to as *milled* or *undermilled rice*.

Undermilled rice is passed through a system of vertical cylinders which gently remove the rough surfaces; the resulting grain is very smooth and is now ready for market as polished rice, although it is not nearly so valuable from a nutritional viewpoint as the brown rice.

In some Oriental countries it is common to make a flour from broken rice, but this is not done in the United States since the food habits of the people do not justify it.

Considerable quantities of broken rice are used in the manufacturing of alcoholic beverages.

AGRONOMIC CLASSIFICATION

Rice varieties may be divided into two principal groups, glutinous and nonglutinous, depending upon the character of the starch deposited within the kernel. By far the most important varieties belong to the common or nonglutinous group.

Varieties are also classified as lowland or irrigated and upland or non-irrigated types. However the irrigated type is much more important as it results in higher yields even with the upland varieties. The terms *upland* and *lowland* do not refer to elevation but to the use of irrigation water.

Based on kernel characters rice is classified as short-, medium-, and long-grained types. The short-grain kernels of American varieties average about 5.5 mm. in length, the medium grain about 6.6 mm., and the long grain about 7 to 8 mm.

WHERE RICE IS GROWN

There are three principal rice-growing areas in the United States:

1. The prairies of southwestern Louisiana and southeastern Texas. This is the most important rice area in North America. Water for irrigation is pumped from streams and wells.

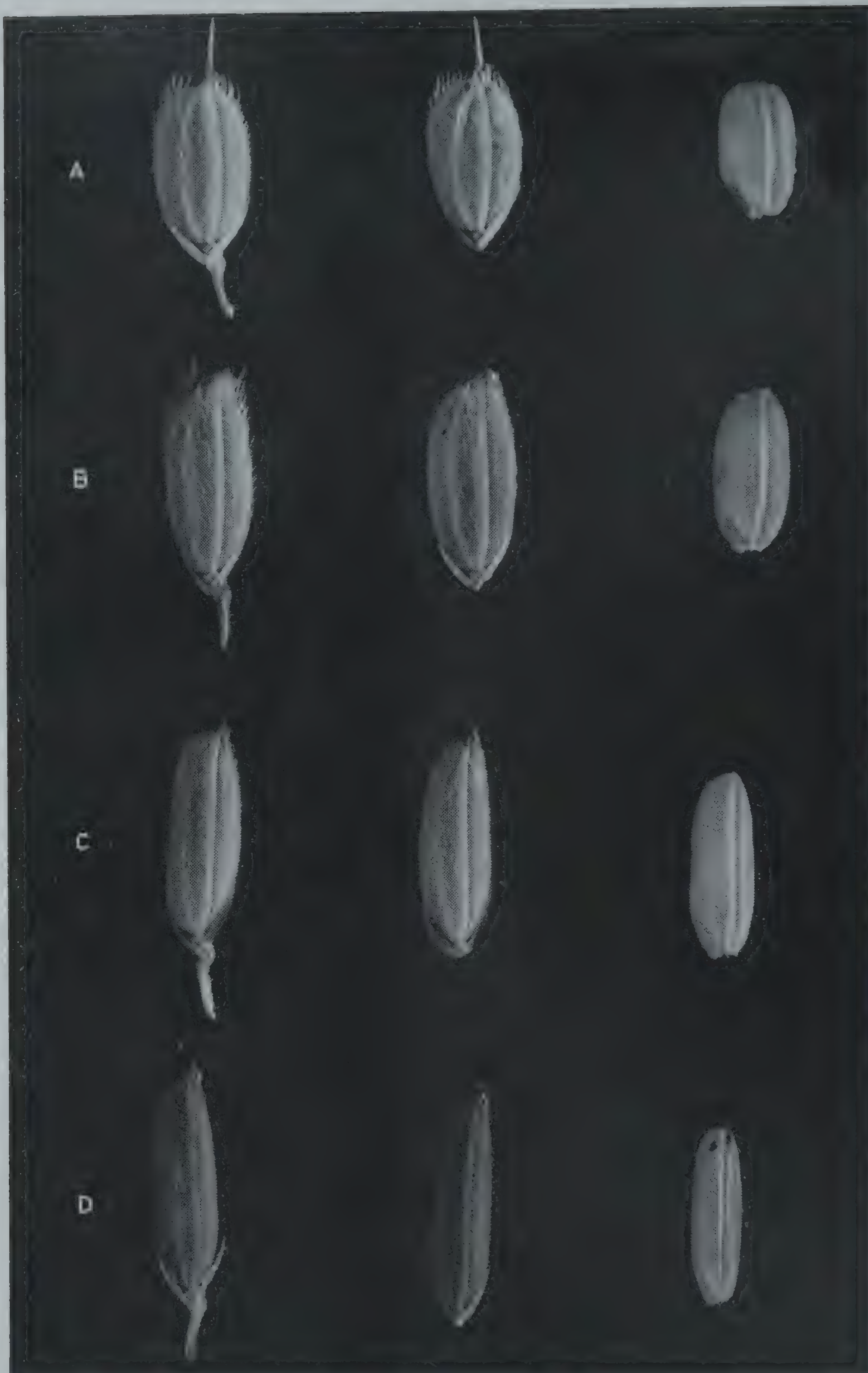


FIG. 77.—Spikelets, seeds, and kernels of rice. *A*, Caloro (short-grain); *B*, Blue Rose (medium-grain); *C*, Fortuna (long-grain); *D*, Rexoro (long-slender-grain). (*Courtesy of Jenkin W. Jones, U.S. Department of Agriculture.*)

2. The Grand Prairie area of eastern Arkansas. Water for irrigation comes largely from wells.

3. The Sacramento and San Joaquin valleys of California. The irrigation water is taken mostly from the Feather and Sacramento rivers.

The importance of the rice crop in the different sections is illustrated in Table 37.

TABLE 37.—AVERAGE RICE ACREAGE, YIELD, PRODUCTION, AND AVERAGE PRICE PER BUSHEL RECEIVED BY FARMERS

State	Acres	Yield per acre, bu., 1945	Total production, bu., 1945	Price per bu., 1943
Louisiana	583,000	39.5	23,028,000	$1.85
Texas	400,000	45.0	18,000,000	1.90
Arkansas	281,000	52.0	14,612,000	1.70
California	242,000	60.0	14,520,000	1.75
United States	1,506,000	46.6	70,160,000	1.82

As shown in Table 37, most of the rice is produced in Louisiana and Texas. In all areas where grown the crop is fairly profitable on an average, although there is considerable expense involved in its production, as will be made more evident in the discussion of culture.

THE CULTURE OF RICE

In the culture of rice, one must consider the following factors: (1) climate, (2) source of irrigation water, (3) soil, (4) rotation, (5) varieties, (6) seedbed preparation, (7) seeding, (8) irrigation, (9) drainage, (10) harvesting, (11) pests, and (12) marketing.

Climate for Rice.—Jones and Jenkins[1] give the following requirements for rice growing. For the satisfactory production of rice it is desirable that the region provide the following:

1. Relatively warm temperatures throughout the growing seasons.

2. An abundant supply of water for proper irrigation.

3. Soils that are fairly level and capable of holding water fairly well without too much seepage.

4. Adequate surface drainage. Drainage is essential to a good stand in the spring and to make it possible to get rid of the water prior to harvest.

Irrigation Water.—In Louisiana and Texas about 48 in. of water is

[1] JONES, JENKIN W., and J. MITCHELL JENKINS, Rice Culture in the Southern States, *U.S. Dept. Agr. Farmers' Bull.* 1808, 1938.

required to produce a crop of rice. On an average about 20 in. of this water is provided by rainfall during the growing season. In general the charges for water range from \$6 to \$9 per acre per season.

In Arkansas it is necessary to provide 24 to 30 in. of water each season, with about 6 in. falling as rain during the growing season. The cost of the water ranges from \$6 to \$10 per acre.

FIG. 78.—A field of young rice plants. (*Courtesy of B. M. King, Missouri Agricultural Experiment Station.*)

Soils.—Almost any productive soil is suitable for rice, but it is grown normally on relatively level medium to heavy soils which are more economical of water and when drained are better suited to support harvesting machines. Frequently these soils are low in organic matter and respond to improvement.

Rotation.—Since levees must be constructed to hold the irrigation water it is difficult to practice a rotation in the normal sense. The common cropping system in Texas and Louisiana is to grow one or more rice crops, graze the land for 1 to 3 years, and then seed to rice again. In some cases the rotation involves clean tillage, cotton, soybeans, corn, and green manure crops, although stubble pasture is most common.

In Arkansas most of the rice land is allowed to lie idle, is planted to soybeans, is fallowed, is planted to oats, corn, cotton, or green manure crops.

In California it is common to alternate rice with summer fallow, with fall-sown wheat or barley occasionally intervening. In some cases the land is pastured as is done in Texas.

Nitrogenous and phosphatic fertilizers have been used to advantage

in Texas, Louisiana, and Arkansas, but results have been so variable that no general recommendations can be made. However, 200 to 300 lb. per acre of a complete fertilizer such as 8–10–6 is recommended in Louisiana. In Texas about 150 lb. per acre of ammonium sulfate and superphosphate have proved advantageous. In Arkansas, growers often apply 150 to 200 lb. per acre of nitrogenous fertilizers.

Variable results with fertilizers have been obtained in California, but ammonium sulfate is extensively used at the rate of 150 to 200 lb. per acre. In some cases a growth of bur clover has proved beneficial, but it entails certain problems of securing a stand and in doing an adequate job of plowing it under as a green manure.

Varieties.—As indicated earlier, the rice varieties are divided into the three groups, short-, medium-, and long-grain types.

The short-grain varieties of Japanese origin are fairly well suited to the prairies of the South and in California. In recent years they have lost much of their popularity in the South with the producers and the consumer, who prefer the medium and long-grain types.

The principal short-grain varieties are Wataribune, Acadia, and Asaki, which are late maturing, and Caloro, a midseason variety. Caloro is grown extensively in California. The seeds are short and broad with short yellowish beards. The variety requires about 155 days from seeding to maturity in California.

Colusa and Onsen are early maturing short-grained varieties that are grown to some extent in California. Improved Caloro (Selection 175) is a pure-line midseason partly awned variety which matures about the same time as Caloro. Onsen is a mixed variety which is about 2 weeks earlier than Caloro. Its tendency to lodge is an undesirable characteristic.

The medium-grain varieties are the most important types grown in the South, with none being of much importance in California, although Calady 40 is grown on a small acreage. The leading medium-grain varieties in the South are Blue Rose, Zenith, and Early Prolific, all of which possess relatively stiff straw and yield well on reasonably fertile soil. Blue Rose is a late-maturing variety, while Zenith and Early Prolific are early.

The long-grain varieties are not grown except on a small acreage in the Imperial Valley of California and are of less importance in the South than the medium-grain types. Their longer seeds tend to result in more broken grains in milling than is generally true of the medium- and short-grain varieties. They command a higher price than the shorter grained varieties, which leads to their preference by many farmers. The prin-

cipal varieties of long-grain rice are Texas Patna, Bluebonnet, Prelude, Nira, Rexoro, Fortuna, Lady Wright. In recent years the varieties Rexoro, Fortuna, Nira, Texas Patna, and Bluebonnet have been most popular because of their greater disease resistance, higher price, and superior quality of grain. Each of these varieties is relatively late in maturing. A more recently developed long-grain variety Bluebonnet has been developed by the Rice Experiment Station at Beaumont, Tex., and the United States Department of Agriculture.

Seedbed Preparation.—The principal objective in the preparation of the rice seedbed is to destroy all weed growth and to ensure a mellow, firm surface which favors rapid germination of the rice. In Louisiana and Texas the land is usually plowed in the fall or early spring. In Arkansas and California nearly all rice land is plowed in the spring since the harvest season is so late that it is impossible as a rule to plow in the fall after harvest.

Seeding.—In the South rice is seeded from Apr. 1 to June 1, with some seeding earlier than April if conditions are favorable. However seeding too early may result in poor germination, as the rice seed rots quickly in cold, wet soil. Some delay to destroy weeds by additional tillage may be desirable.

In California, rice is seeded from Apr. 15 to June 1, the best yields being obtained on an average from the earlier plantings.

In the South 90 to 100 lb. of clean seed per acre is a common rate when drilled and 125 and 150 lb. when broadcast. The objective is to is seed heavily enough to ensure a good stand that may check weed growth.

In California, rice is seeded at the rate of 135 to 150 lb. per acre. Rice may be seeded on clean land with a grain drill or it may be broadcast, but the latter is not a common practice. In California the airplane is used to seed the crop on submerged land. This has proved speedy and efficient. The water is held 4 to 8 in. deep until the land is drained prior to harvesting. This method of irrigation controls weeds.

Irrigation.—In the South when the young rice plants reach a height of 6 to 8 in., the fields are flooded to a depth of 1 to 2 in. As the plants grow, more water is added until it reaches a depth of 4 to 6 in. Water is added from time to time to replace that lost by evaporation, transpiration, and seepage so as to maintain a depth of about 5 in.

Jones[1] reports that trials at the Biggs, California, Station show that seeding rice on the water required about 15 lb. less seed per acre than planting on dry soil followed by continuous submergence.

[1] Jones, Jenkin W., How to Grow Rice in the Sacramento Valley, *U.S. Dept. Agr. Farmers' Bull.* 1240, revised 1940.

Drainage.—Before the crop is fully matured the water is drained from the rice field to make machine harvesting possible. Usually the water is drained off when the rice is fully headed and the panicles are turned down and ripening in the upper portions. As a rule this is about 2 weeks before maturity. Water is allowed to drain from the fields by making breaks in the levees which are used to confine the water on the level.

FIG. 79.—Flooding the rice field. (*Courtesy of B. M. King, Missouri Agricultural Experiment Station.*)

Harvesting.—Rice, like other small grains, is ready for harvest when the seeds in the lower part of the panicle are in the hard-dough stage. Usually this will be about 10 to 18 days after drainage of the water from the field. The crop is cut with a binder or combine, as is done with other grains. It is desirable to have an auxillary engine on the binder or a power take-off from the tractor, since it may not operate well when the soil is muddy or wet if the power must be transmitted from the bull wheel. Where the combine is used, the rice is dried artificially. When the shocked grain is thoroughly dried, it is threshed with an ordinary stationary threshing machine. Care should be taken to adjust the cylinder teeth properly so as to reduce the percentage of broken kernels which greatly lower the value of the crop.

Since the proper harvesting of rice is so definitely related to the quality of the product and the subsequent returns, it is deserving of considerable attention. Smith and Jones[1] have prepared an excellent

[1] SMITH, W. D., and JENKIN W. JONES, When to Cut Rice, *U.S. Dept. Agr. Leaflet* 148, 1937.

paper dealing with this subject. They state that the best yields of the highest quality of rice are obtained when the crop is harvested when the rice grain contains 23 to 28 per cent moisture.

Pests of rice include weeds, insects, and diseases, with weeds probably being the most serious problem faced by most farmers.

In the South the most troublesome weeds are red rice (*Oryza sativa*), which has a red seed coat, curly indigo (*Aeschynomene virginica*), Mexican weed (*Caperonia palustris*), tall indigo (*Sesbania macrocarpa*), barnyard grass (*Echinochloa crus-galli, E. colonum*), sedges (*Cyperus spp.*), nigger wool (*Fimbristylis autumnalis*), alligator head (*Diodia teres*), seaweed (*Sphenoclea Zeylanica*), turtle back (*Commelina virginica*), and smartweed (*Polygonum acre*).

In California the worst weeds of rice fields are the barnyard grasses, umbrella plants, cattails (*Typha latifolia*), water plantain (*Alisma plantago*), arrowhead (*Sagittaria latifolia*), spike rush (*Eleocharis palustris*), red stem (*Ammannia coccinea*), joint grass (*Pospalum distichum*), water hyssop (*Bacopa rotundifolia*), and bulrush (*Scirpus fluviatilis*).

Red rice is the most serious weed, particularly in the South. It is spread usually through mixtures with cultivated rice, and the seeds remain viable in the soil for many years. The best control lies in the use of clean seed, fallow, and ensuring heavy stands of rice. Many of the weeds are destroyed rather effectively after a long period of submergence.

Insects do not cause much trouble to the rice grower as a rule. In the South the principal injurious insects are the rice stinkbug (*Solubea pugnax* F.), the rice water weevil (*Lissorhoptrus simples* Say.), stem borers (*Chiloplejadellus Zincker* and *Diatraea Saccharalis* F.), and the sugar-cane beetle (*Euetheola rugicepa* Lec.).

The stinkbug sucks the juices from the rice kernel while it is immature. Late varieties appear to be most susceptible, probably because the insects are most numerous late in the season.

The rice water weevil larvae feed on the roots of the rice plant and in Arkansas have caused serious losses.

The stem borers bore into the stem and feed on the stalk, which causes the heads to turn white and fail to produce grain.

The sugar-cane beetle eats the stem of the plant near the surface and causes mature plants to lodge.

In California comparatively little damage has been done by insects.

Sanitation, crop rotation, and prevention appear to be the most promising means of controlling these pests.

Several diseases attack the rice plant in the Southern states, but only a few are of economic importance. Some of the most serious to stands

are the seedling blights, which are caused by seeding too early when conditions are favorable for the fungus and not for the rice plant.

Stem rot (*Leptosphaeria salvinii* Catt.) is a fungus disease that attacks the leaf sheaths and stems of plants at the water line, causing a decay of the stem. It may be checked by drainage about 6 weeks prior to maturity and then keeping the land wet but not submerged.

Leaf spots caused by the fungi *Helminthosporium oryzae* V. B. de Haan, *Cercospora oryzae* Miyake, and *Piriculiara oryzae* Car. are most serious diseases and may reduce yields and result in reduced quality of grain. The best control appears to lie in the use of resistant varieties.

Marketing.—Some farmers tend to harvest their rice a little too early in an attempt to gain the advantage of better prices for the early crop. Often this results in lower yields and reduced quality so that the practice is undesirable.

The market value of rice depends upon its milling quality. As the trade uses the term, milling quality refers to the percentage of whole kernels and of total milled rice that can be obtained under average milling conditions from a given quantity of rough rice.

The rice when it goes to market may be graded according to Federal standards as to variety and type and by a numerical grade based on factors other than milling quality. The use of Federal standards is permissive but is not compulsory. Then the milling quality is determined and is made a part of the grade designation.

WILD RICE

Wild rice (*Zizania aquatica* L.) is an annual plant that grows largely in the shallow lakes of the Northern border states. Probably it is found more generally in Minnesota than in any other area of the United States.

The plant is native to those regions where it grows, and if properly managed it continues to reseed and to reproduce indefinitely.

For the most part the seed is sold as a luxury food, to be used by many as a supplement to wild game such as duck or pheasant. In some areas the Indians depend upon wild rice as a staple article of food.

Most of the wild rice is harvested by Indians, although a few white men are granted licenses to gather the seed. To avoid destruction of the rice beds, it is necessary to harvest only a portion of the crop, thus leaving ample seed for the next crop. In Minnesota, for example, the law prohibits the use of machinery, and all rice is harvested by hand from canoes.

Following harvest the rice is carefully dried, parched, the hull removed, and the grain is placed on the market for a special clientele.

CHAPTER XIV

BUCKWHEAT

Buckwheat is one of the minor grain crops grown in America. Many farmers have never seen the crop grow, and many are unfamiliar with the principal product, buckwheat flour. The rather distinctive flavor of buckwheat flour is of such character that it is either greatly liked or almost as enthusiastically disliked. It has been said that if one did not acquire a liking for buckwheat cakes while a youngster he probably would never care for them as an adult. Although many pancakes are consumed in the United States, the majority are made of flours other than buckwheat, or if buckwheat flour is used, in many cases it forms but a limited percentage of a flour mixture.

TABLE 38.—AVERAGE ACREAGE AND PRODUCTION IN BUSHELS OF BUCKWHEAT IN THE UNITED STATES
1933–1942

State	Acres	Bushels
New York	134,000	2,333,000
Pennsylvania	127,000	2,423,000
Michigan	23,000	333,000
West Virginia	16,000	292,000
Ohio	17,000	285,000
United States total	416,000	7,020,000

IMPORTANCE AND DISTRIBUTION

Buckwheat is grown to but a limited extent in the United States. Quisenberry and Taylor[1] state that for every bushel of buckwheat raised in this country about 300 bu. of corn, 100 bu. of wheat, 150 bu. of oats, 35 bu. of barley, and 5 bu. of rye are produced. The leading states in buckwheat production are New York and Pennsylvania, which together normally produce more than one-half of the total United States crop.

[1] QUISENBERRY, K. S., and J. W. TAYLOR, Growing Buckwheat, *U.S. Dept. Agr. Farmers' Bull.* 1835, 1939.

BOTANICAL CLASSIFICATION

Buckwheat is a member of the Polygonaceae or buckwheat family and is related to such common weeds as dock, wild buckwheat, and sheep sorrel. The principal species of economic importance are *Fagopyrum esculentum, F. tataricum,* and *F. emarginatum.*

Fig. 80.—Buckwheat bears pinkish-white flowers in flat-topped clusters in the axils of the leaves and at the ends of the stems or branches. Buckwheat continues to bloom throughout the fruiting season, and this continuous blossoming habit ensures at least a partial crop of grain even if most of the early flowers are blasted. (*Courtesy of J. W. White, Pennsylvania Agricultural Experiment Station.*)

The plants are highly self-sterile and must be cross-pollinated. As a result, many hybrids occur and varieties of buckwheat tend to be badly mixed. Buckwheat has an indeterminate type of growth, *i.e.*, it continues to grow until frost, so that when harvested the plants may have buds, blossoms, and mature seeds at the same time.

VARIETIES OF BUCKWHEAT

The principal varieties grown in the United States are Japanese and Silverhull, both belonging to the species *F. esculentum.* It is not uncommon to find the two varieties grown as a mixture, since they readily hybridize, making it difficult to maintain a pure variety.

Japanese has a brown to dark-brown seed which is usually much

larger than that of Silverhull. The seeds are triangular and wing-shaped so that the sides are concave, although when grown under field conditions many of the seeds do not show these characteristics.

Silverhull usually produces smaller seeds which are silvery gray in color and have sides that tend to be convex, giving the seed the appear-

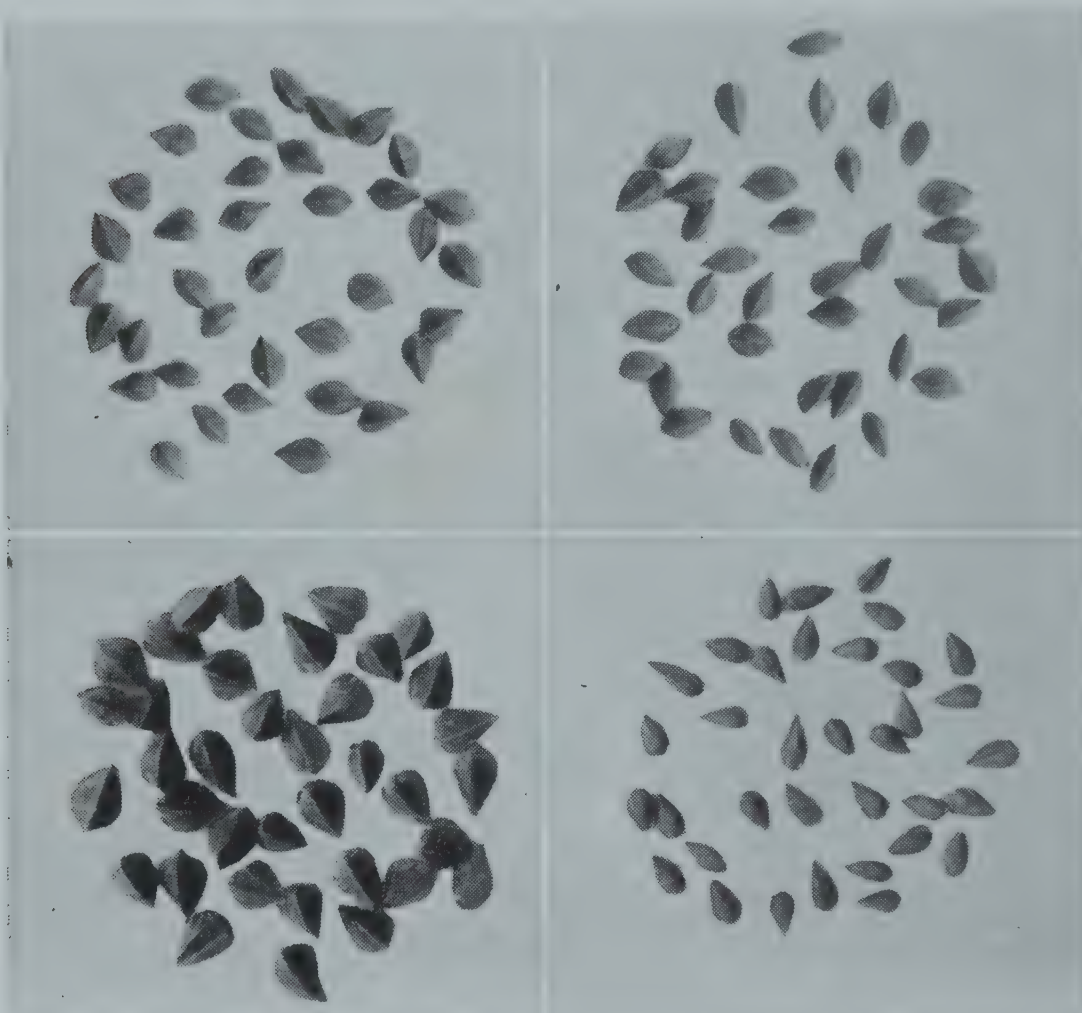


FIG. 81.—Buckwheat seed of four varieties, natural size, left to right: upper, Common, Silverhull; lower, Japanese, Tartary. Common is not a true variety but consists of borderline seed or mixed strains of Japanese and Silverhull produced as results of cross-pollination. (*Courtesy of J. W. White, Pennsylvania Agricultural Experiment Station.*)

ance of being almost round rather than triangular. In general, Silverhull produces smaller plants than Japanese and shows a tendency to develop more red color in the stems at maturity.

Japanese and Silverhull are the most extensively grown varieties and alone or in combination make up the principal buckwheat acreage in the United States.

A variety known as Common or Common Gray is grown to a limited

extent in some sections, although Quisenberry and Taylor state that this variety is probably identical with Silverhull.

Tartary buckwheat, sometimes called rye buckwheat, belongs to the species *F. tataricum* and does not hybridize with the other varieties. The seeds of Tartary are small, being near the size and shape of rye kernels, with colors ranging from dull gray to black. In contrast with the other varieties of buckwheat, Tartary has very small flowers which are self-fertile. It is grown on limited acreages in North Carolina, Maine, New York, Pennsylvania, and Maryland. It is known under various names such as duckwheat, Marino, Mountain, Siberian, wild-goose, rye buckwheat, hull-less, bloomless, etc.

TABLE 39.—PERCENTAGE OF TOTAL DIGESTIBLE NUTRIENTS OF THE GRAIN AND STRAW OF COMMON GRAIN CROPS

	Buckwheat	Barley	Oats	Rye	Wheat	Corn
Grain	64.4	78.7	71.5	80.1	83.6	83.7
Straw	32.3	44.5	44.1	41.2	35.7	54.6

Tartary buckwheat is not suitable for flour, since the flour has a dark color and a bitter taste. Many processors refuse to purchase Tartary, and most of that raised is fed to poultry.

Notch or wing-seeded buckwheat (*F. emarginatum*) is of little importance, sometimes occurring as an admixture with other varieties. The variety may be recognized by the wide margins or wings that develop in the angles of the seed coat.

USES OF BUCKWHEAT

The principal use of buckwheat is for the making of a flour to be used in the preparation of pancake flours. Probably the greatest percentage is used not in pure buckwheat flour but in mixtures with flours from other cereals to produce a flour that is not so strong in flavor as the pure product. Some persons are allergic to the protein in buckwheat and develop a skin rash following the eating of buckwheat products.

The grain of buckwheat provides a good feed which contains a little less crude protein than wheat, rye, and oats and about the same amount as corn.

Morrison[1] reports that, on the basis of total digestible nutrients of both grain and straw, buckwheat ranks below the common grain crops.

[1] MORRISON, F. B., "Feeds and Feeding," 20th ed., The Morrison Publishing Co., Ithaca, N. Y., 1936.

The whole grain is often placed in poultry scratch-feed mixtures. The by-products from milling flour provide feed that is satisfactory for most classes of livestock, particularly cattle. According to Morrison, buckwheat middlings offer a very satisfactory protein supplement for dairy cows, provided that they do not form more than one-third of the concentrate mixture.

Buckwheat straw is richer in protein than the straw of the cereals, but it is lower in digestible carbohydrates and fats than corn stover or cereal straw. As a bedding it is not satisfactory for cattle as it decomposes rather rapidly.

FIG. 82.—A field of buckwheat in the shock. (*Courtesy of J. W. White, Pennsylvania Agricultural Experiment Station.*)

Buckwheat has been credited widely as a valuable weed-controlling crop. It is satisfactory in the smothering of certain weeds such as quack grass, provided that the seedbed is well prepared and the buckwheat is given a chance to get started ahead of the quack. It has proved unsuccessful, however, in the elimination of persistent, deep-rooted weeds such as field bindweed. Where buckwheat is used for weed control, it is desirable to seed at a heavy rate, 4 to 5 pecks per acre.

Buckwheat is used by some farmers to build up the productivity of the soil since it will grow on very poor and infertile types, although this practice is of doubtful value.

White[1] and his associates have shown that the buckwheat plant is a heavy user of plant food, and thus yields of crops following buckwheat

[1] White, J. W., F. J. Holben, and A. C. Richer, Experiments with Buckwheat, *Pa. Agr. Expt. Sta. Bull.* 403, 1941.

may be reduced. However, when the crop is turned under as a green manure it has value in soil improvement.

White and his associates also state that 2 tons of green buckwheat in full blossom supplies plant food equivalent to that contained in 135 lb. of sulfate of ammonia, 62 lb. of 16 per cent superphosphate, and 80 lb. of 50 per cent muriate of potash. Such practices do not effect a real improvement of the soil, since it makes the plant food available without adding to its supply.

In some cases rye is combined with the buckwheat and the entire crop plowed under. This practice is not general, however, as it probably is not justified except under extreme conditions where the benefits can justify the rather high cost of the practice.

Buckwheat is a valuable winter cover crop, particularly in orchards where it checks the fall growth of trees through the removal of available plant food, aids in erosion control, and forms a cover to catch the snow.

Honey producers in some areas, particularly in New York and Pennsylvania, use buckwheat as a honey plant, as buckwheat produces an abundance of flowers late in the season when other flowers may be scarce. The buckwheat plant produces much nectar during the late summer when supplies are likely to be low. Cormany[1] estimated that an acre of buckwheat might yield enough nectar to produce 100 to 150 lb. of honey.

The honey from buckwheat is dark in color and has a distinctive flavor which is prized by those who like it and rather generally disliked by those who have not acquired an appreciation for the rather strong flavor.

CULTURE OF BUCKWHEAT

Rotation.—Buckwheat is often grown in small fields and frequently does not fit into a definite rotation. As it is a crop that succeeds on rather poor soils, it is often grown on unproductive land, which tends to become more unproductive as a result of growing buckwheat. Commonly when a rotation is followed, it is grown in much the same place as any other crop of small grain. Many farmers seed buckwheat as an emergency crop to replace other grain crops that have been lost as a result of hail, floods, or other causes. Probably too many growers tend to seed the crop because they are able to produce a fair crop on land whose level of fertility is low. Such a practice may aggravate a bad situation.

[1] Cormany, C. E., Buckwheat in Michigan, *Mich. Agr. Expt. Sta. Bull.* 151, 1926.

SOILS FOR BUCKWHEAT

The ability of buckwheat to grow under such a wide range of soil conditions has no doubt been partly responsible for its general use on the less productive soils. White and his associates state that buckwheat should not be grown on soil sufficiently fertile for the profitable production of other grains. They do advise, however, that sufficient phosphorus be added to the soils to ensure profitable crops.

Seeding.—The seedbed is prepared much the same as for other small grains, the crop being seeded any time after the weather is warm. Most seedings are made in New York and Pennsylvania from June 15 to July 5. About 10 to 12 weeks should be allowed for growth before the first killing frost may be expected.

Buckwheat is seeded with a drill or sown broadcast much the same as wheat or oats. A common rate of seeding is 3 to 4 pecks per acre, although with the smaller seeded Tartary type 2 pecks per acre is usually sufficient.

Harvesting.—The crop is harvested before frost, using the binder or combine, and as far as possible when the maximum number of seeds are ripe. Shattering losses may be reduced by harvesting when the dew is on or on a damp day. The crop is left in the fields until dry as it is full of moisture at the time of harvest. It may be stacked or threshed directly from the shock, taking care in handling to reduce seed shattering. In threshing it is desirable to remove the spiked concaves to prevent cracking the seeds.

MILLING OF BUCKWHEAT

The legal bushel weight of buckwheat in most states is 48 lb. The seed is milled much the same as wheat. The grain is cracked to loosen the hulls, and the flour is sieved after successive grinding operations. According to Quisenberry and Taylor, on an average, 100 lb. of dry buckwheat will yield 60 to 75 lb. of flour, 4 to 18 lb. of middlings, and 18 to 26 lb. of hulls. If the miller produces a pure white flour, he cannot obtain more than about 52 lb. of flour from 100 lb. of grain. As a rule, the flour is not milled to a pure white flour but carries numerous particles of hull, giving the flour a characteristic dark color. Coe[1] states that the demands of the consumers vary in different localities, the Eastern trade preferring a white flour, while the Western trade shows preference for a dark flour containing middlings and fine particles of

[1] Coe, Wayne R., Buckwheat Milling and Its By-products, *U.S. Dept. Agr. Circ.* 190, 1931.

bran. In other areas there is a demand for an intermediate type of flour.

BUCKWHEAT IN MEDICINE

Buckwheat has come into prominence as a source of rutin, a flavonol glucoside that has proved effective in the treatment of increased capillary fragility associated with hypertension, or high blood pressure, in man. Couch, Naghski, and Krewson[1] have reported on the possibilities of buckwheat as a crop that may prove of great value to medical research and mankind. It appears that the increased use of rutin may result in buckwheat becoming an important cash crop.

Review Questions

1. Why is most of the buckwheat grown in America produced in New York and Pennsylvania.
2. How does buckwheat serve as an emergency crop?
3. Explain the place of buckwheat as a honey plant.
4. Why do not more people eat pure buckwheat flour?
5. Why are some people allergic to buckwheat cakes?
6. How exacting is buckwheat as to soil fertility?
7. Describe the milling process.
8. What is meant by indeterminate growth as applied to buckwheat?
9. How satisfactory is buckwheat as a livestock feed?
10. About how many weeks does it take to produce a crop of buckwheat?
11. What is the place of buckwheat as a cover crop?

References

CARLETON, M. A.: "The Small Grains," The Macmillan Company, New York, 1924.

HUGHES, H. D., and E. R. HENSON: "Crop Production," The Macmillan Company, New York, 1930.

QUISENBERRY, K. S., and J. W. TAYLOR, Growing Buckwheat, *U.S. Dept. Agr. Farmers' Bull.* 1835, 1939.

WHITE, J. W., F. J. HOLBEN, and A. C. RICHER: Experiments with Buckwheat, *Pa. Agr. Expt. Sta. Bull.* 403, 1941.

[1] COUCH, JAMES F., JOSEPH NAGHSKI, and CHARLES F. KREWSON, Buckwheat as a Source of Rutin, *Science*, Vol. 103, No. 2668, 1946.

CHAPTER XV

THE MILLETS

The millets as a group are used for both forage and grain. Usually the proso types are grown for their seed. Some types such as the foxtail millets may be used for either hay or seed. Here, the millets are considered as seed crops only.

CLASSIFICATION

The millets are annuals of the grass family but include several genera. The principal species grown in America for their grain are the following:

Proso, or hog millet, *Panicum miliaceum*
Foxtail millet, *Setaria italica*

Other species are grown in the United States, but primarily as forages.

Proso.—This, the principal grain millet, has an inflorescence which is a large spreading panicle much like that of oats. The stalks, 12 to 48 in. in height, are coarse and of little value except for bedding. The seeds are usually larger than those of the foxtail types and vary in color, including white, cream yellow, red, brown, and black.

The flowers may be either self- or cross-fertilized, so that varieties are often mixed.

The principal varieties of proso millet are Turghai, Red Russian, Tambov, White Ural, Yellow Manitoba, Black Voronezh, and Early Fortune. The Turghai variety has yellowish-brown seeds; Tambov, Early Fortune, and Red Russian seeds are reddish brown; the colors of the other varieties are indicated by their names.

Foxtail.—The foxtail types are 24 to 48 in. in height, and the inflorescence is a dense spike. The rather small seeds vary in color much the same as the proso types. They are not so shiny as the seeds of proso, which look as though they had been varnished.

The principal varieties of foxtail millet are as follows:

Common: straw-colored seeds
German: straw-colored seeds, lobed heads
Siberian: a mixture of straw-colored seed and reddish-orange seed
Hungarian: a mixture of brown to black and yellow seeds
Kursk: orange seed

The millets are relatively unimportant, being grown most extensively in regions of limited water supply. Martin[1] states that proso has the lowest water requirement of any grain crop. The principal millet-growing states are Colorado, South Dakota, Tennessee, and Kansas. In Tennessee and Kansas considerable acreages of the foxtail types of millet are grown, but in the more northern states it is primarily proso. In many areas it is felt that millet should be grown only as a last resort, either because of insufficient rainfall for the other grain crops or insufficient time to mature other crops. In general, most farmers do not grow the millets from choice but more or less from necessity.

FIG. 83.—Left, common millet. Center, Japanese millet or barnyard grass. Right, proso or hog millet. (*After Rather.*)

The proso millets are earlier maturing than the foxtail types and are more generally used for grain purposes. Most of the foxtail millet is grown for its forage, for which purpose it is much better suited than proso.

When conditions are very favorable, yields of 50 to 60 bu. of proso may be secured, but 15- to 25-bu. yields are much more common. As a rule, the foxtail types produce somewhat less grain than the proso.

Millet is spring-sown but may be planted later than most other grain

[1] MARTIN, J. H., Proso or Hog Millet, *U.S. Dept. Agr. Farmers' Bull.* 1162, revised 1937.

crops. Farmers in the Northwest often seed and mature a crop after July 1.

USES OF MILLET

Although the millets are suitable for food, being so used in the Far East, they are of no importance for this purpose in America.

Most of the proso millet is used as a feed for livestock, primarily for hogs as a substitute for other grains. Early work indicates that a bushel of proso weighing 48 lb. is required to produce the same gain on hogs as

FIG. 84.—A field of German millet.

a bushel of barley weighing 48 lb. The Colorado station found that proso when fed to lambs and pigs was about equal to corn or barley. Goodearl[1] in a comparison of proso millet with yellow corn as a feed for laying hens reported that, with corn as 100 per cent efficient as a measure of egg production, proso millet was 107 per cent efficient for White Leghorns but only 96 per cent as efficient for Rhode Island Reds. The author concludes that in a mash or grain mixture for laying hens it is possible entirely to replace yellow corn with proso millet.

Foxtail millet is of much the same composition as proso and may be fed to the same classes of livestock. Both types are ideal for poultry and are often used in commercial bird seed.

[1] GOODEARL, G. P., Comparison of Proso Millet and Yellow Corn for Feeding Laying Hens, *N. D. Agr. Expt. Sta. Bull.* 329, 1943.

None of the millets should be fed to horses as their use has a harmful effect upon the kidneys.

CULTURE OF MILLET

The culture of millet is very much the same as for other grains. As indicated previously, the crop may be seeded later than most grains. The seed will not germinate in cold, wet soil, so it is necessary to delay planting until the ground is warmed thoroughly.

When seeded with a grain drill under humid conditions proso is planted at the rate of 28 to 40 lb. per acre. Under drier conditions the rate may be decreased to as low as 15 lb. per acre. The foxtail types of millet may be seeded at a lower rate since the seeds are much smaller, although a common rate in the humid areas is 30 to 35 lb. per acre. If the seed is sown broadcast, the rates must be increased to offset the greater irregularity in covering the seed.

The crop is harvested early enough to avoid shattering of the mature seed. As a rule proso is cut when the seeds in the upper part of the panicle are ripe and the plants still green. Similarly, the foxtail millets are harvested as soon as the seeds are in the dough stage to avoid shattering. The crop may be harvested the same as other small grains. If the binder is used, small shocks are essential to ensure rapid drying of the green straw.

Care must be exercised in threshing to avoid considerable cracking, as the seeds are easily separated from the straw.

While there is no accepted national legal bushel weight for millet, common bases are proso millet, 56 lb., and foxtail types, 50 lb. In some states, the accepted legal weight is 50 lb. for all millets.

Review Questions

1. Why is proso often referred to as hog millet?
2. In what characteristics do the seeds of millet resemble other grains?
3. What are the principal varieties of proso millet?
4. Why is millet so valuable as an emergency crop?
5. Be able to differentiate between and recognize the different varieties of millet.
6. When should millet be seeded?
7. What uses may be made of the millets as grain crops?
8. How much seed is required to plant an acre of the different types of millet?
9. Why should millet grain never be fed to horses?
10. Why is millet generally believed to be hard on the soil?

References

Christensen, F. W., P. E. Johnson, Al Severson, E. P. Painter, and T. H.

HOPPER: Proso, Corn, and Barley as Feeds for Hogs on Alfalfa Pasture, *N. D. Agr. Expt. Sta. Bull.* 318, 1942.

CURTIS, J. J., J. F. BRANDON, and D. W. ROBERTSON: Proso or Hog Millet in Colorado, *Colo. Agr. Expt. Sta. Bull.* 438, 1937.

———, ———, and R. M. WEIHING: Foxtail Millet in Colorado, *Colo. Agr. Expt. Sta. Bull.* 461, 1940.

GOODEARL, G. P.: Comparison of Proso Millet and Yellow Corn for Feeding Laying Hens, *N. D. Agr. Expt. Sta. Bull.* 329, 1943.

HUGHES, H. D., and E. R. HENSON: "Crop Production," The Macmillan Company, New York, 1930.

PIPER, C. V.: "Forage Plants and Their Culture," The Macmillan Company, New York, 1920.

WILSON, J. W., and T. WRIGHT: Proso as a Fattening Feed for Swine, *S. D. Agr. Expt. Sta. Bull.* 316, 1938.

CHAPTER XVI

SOYBEANS

For many years in America the soybean was considered primarily as a forage crop and was not discussed generally in a grain-crops course. Today the situation has changed greatly, as the soybean has come to be one of our very important grain crops. For the years 1927–1931, soybean for seed acreage averaged 1,114,000 yearly with a production of 15,845,000 bu. In 1945 the acreage was 10,873,000 with a production of 191,722,000 bu., an increase of nearly 1,200 per cent.[1]

For many generations the soybean has been a prime source of protein food in China, and it has been an important factor in enabling millions of people to live in that great country. In America the soybean as a grain has come to be important largely because of its valuable oil, which in many cases enters into the processing of foods and is thus indirectly a factor in human welfare as well as serving for a multitude of other uses.

Even in America there has been a decided increase in the use of the soybean for food. The vegetable types gained greatly in popularity during the Second World War, and there has been an increased use of the grain type of soybean in human foodstuffs.

WHERE ARE SOYBEANS GROWN?

The corn belt is the center of soybean production for grain, although some soybeans are grown commercially in nearly every state. The principal states growing soybeans for grain are listed in Table 40.

While the soybean is grown in both the North and the South, it appears to be best adapted for seed production in the states of the corn belt. In Illinois, Iowa, Indiana, Ohio, and Missouri the soybean has come to be a very important crop, and because of its great increase in these states, there has been a corresponding decrease in certain of the grain crops, particularly oats and to a lesser extent corn. Many of the growers use the crop for both grain and hay, varying the usage with the season, the market demands, and the need for a hay crop.

Many farmers have come to raise the soybean because they found it a relatively easy crop to grow. It will succeed on a wide variety of soils, and unlike alfalfa it does not require soils with a high content of calcium.

[1] Crop Production, Annual Summary, *Bureau Agr. Econ., U.S. Dept. Agr.*, 1944.

For these and other reasons, acreages have increased greatly in many areas where the soils are deficient in lime. The soybean is truly the poor man's clover, as it does well on low-fertility soils. When the demands are great for the dry beans, then the tendency is to use a greater percentage of the crop for market as dry beans; in years when market demands are not so great, then farmers tend to use a greater percentage of the crop for forage.

TABLE 40.—HARVESTED ACREAGE AND PRODUCTION IN BUSHELS OF SOYBEANS IN LEADING STATES, 1945

State	Acres	Bushels
Illinois	3,800,000	74,100,000
Iowa	1,936,000	34,848,000
Indiana	1,432,000	27,924,000
Ohio	1,147,000	20,072,000
Missouri	730,000	9,490,000
Minnesota	455,000	6,825,000
Kansas	274,000	2,740,000
North Carolina	216,000	2,700,000
Arkansas	209,000	3,344,000
Michigan	122,000	1,952,000
United States total	10,873,000	191,722,000

BOTANICAL CLASSIFICATION

The soybean is a member of the legume family. While there has been some dispute as to the proper name, Morse and Cartter[1] classify it as *Soja max.* (L.) Piper.

Morse and Cartter[2] state that the soybean has been referred to in literature as *Glycine hispida* (Moench) Maxim. but that extensive studies by Piper led to the conclusion that the proper name was *Soja max.* (L.), although some investigators consider the proper name to be *G. max.* (L.) Merrill.

Morse and Cartter report that many investigators believe the present soybean came from *G. ussuriensis* Regel and Maack, a species growing wild in eastern Asia.

The plant is a summer annual which ranges in maturity requirements

[1] MORSE, W. J., and J. L. CARTTER, Soybeans: Culture and Varieties, *U.S. Dept. Agr. Farmers' Bull.* 1520, revised 1939.

[2] MORSE, W. J., and J. L. CARTTER, Improvement in Soybeans, *U.S. Dept. Agr., Yearbook of Agriculture*, 1937.

from about 75 days for the early to 200 days or more for the very late varieties. In appearance it resembles the ordinary garden bean except that usually the leaves are pubescent. Small inconspicuous white or purple flowers are borne in the axils of the leaves. The soybean is normally self-pollinated, although Garber and Odland[1] state that some cross-pollination (less than 1 per cent) occurs under normal conditions, a not uncommon situation among self-pollinated species.

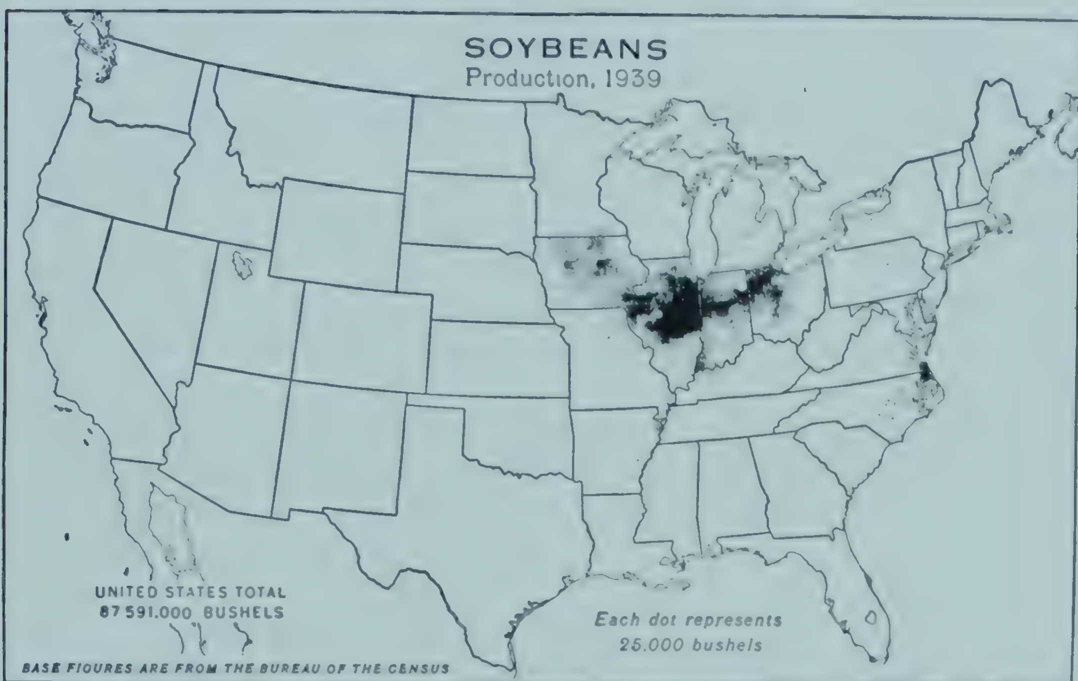


FIG. 85.—The soybean acreage is concentrated in the corn belt. (*Courtesy of the U.S. Department of Agriculture.*)

Seed colors range from straw yellow, greenish yellow, green to brown, to black. In some cases the colors are combined to produce a bicolored pattern, although these varieties are not so common as the one-colored types.

AGRONOMIC CLASSIFICATION

In general, soybeans are grown for three purposes: seed, forage, and use as a vegetable. Many of the varieties are used interchangeably for seed or forage, while relatively few are suitable for use as a green vegetable or cooked as a dry bean. During recent years, increased attention has been given to the food possibilities of the soybean.

For seed production the yellow-seeded varieties are usually preferred for the manufacture of oil and food. The forage types are usually finer

[1] GARBER, R. J., and T. E. ODLAND, Natural Crossing in Soybeans, *J. Am. Soc. Agron.*, **18**:967–970, 1926.

stemmed and more leafy, and their seeds do not produce as much oil. By seeding the grain types at a heavier rate, the same varieties serve very well for forage.

MARKET CLASSIFICATION

The Federal grain standards[1] define soybeans as "any grain which before the removal of dockage, consists of 50 per cent or more of threshed soybeans and not more than 10 per cent of other grains for which standards have been established under the provisions of the United States Grain Standards Act."

There are five market classes of soybeans based on the color of seed:

Yellow Soybeans
Green Soybeans
Brown Soybeans
Black Soybeans
Mixed Soybeans

The standards include four numerical grades and Sample Grade for distinctly low-quality beans. The principal grading factors are weight per bushel, moisture, damaged beans, and foreign material other than dockage.

VARIETIES OF SOYBEANS

There are very many varieties of soybeans grown in this country. Morse and Cartter[2] give a description of the principal varieties grown in America. The student should become familiar with the varieties which are recommended by his state agricultural experiment station. It should be remembered that the so-called *forage* varieties are generally not so suitable for seed production as the true seed types. Whether one grows soybeans for seed or not will depend upon his location and the relative market demands. When the demand is active, the soybean usually serves as a profitable grain crop.

USES OF THE SOYBEAN

The soybean is a plant of many uses. Piper and Morse[3] list some

[1] Handbook of Official Grain Standards of the United States, *U.S. Dept. Agr., United States Grain Standards Act Form* 90, 1941.

[2] Morse, W. J., and J. L. Cartter, Soybeans: Culture and Varieties, *U.S. Dept. Agr. Farmers' Bull.* 1520, revised 1939.

[3] Piper, C. V., and W. J. Morse, "The Soybean," McGraw-Hill Book Company, Inc., New York, 1923.

50 different products. The uses may be summarized under a few main heads:

Seed or grain crop
Forage
Green manure
Dried edible beans and products
Green vegetable

Seed or Grain Crop.—This is the principal use of the soybean and the only one with which we are concerned in this text. The beans are crushed for their oil, which ranges in percentage from about 15 to 23. The increased use of soybean oil is remarkable. According to Cox,[1] less than 36,000,000 lb. of soybean oil was consumed in America in 1931, but in 1942 more than 718,000,000 lb. was utilized, an increase of 2,000 per cent. It must be recognized that this increase was largely the result of war conditions, and whether soybean oil will maintain its place of importance cannot be predicted with certainty.

On many farms the seed varieties may be used for forage in case the grower so desires.

Although soybean oil is not so fast-drying an oil as linseed oil, it is used in the manufacture of paints. Cox states that a mixture of 40 per cent perilla and 60 per cent soybean oil produces a degree of hardness in paints similar to that of raw linseed oil.

Other uses of soybean oil include the manufacture of glycerin, explosives, enamels, butter substitutes, linoleum, soaps, rubber substitutes, ink, and lubricating oils.

The meal that remains after the separation of the oil is rich in protein and is highly prized as a livestock feed. The whole bean may be fed to hogs, but too heavy feeding may result in a "soft pork" and a market discount. The meal, however, may be used satisfactorily for all classes of livestock.

CULTURE

Although a legume, the soybean, when grown for seed, is a soil-depleting crop and must be classed much the same as corn, oats, and wheat in relation to its demands on fertility, except that when properly inoculated the plant is able to secure nitrogen from the atmosphere. However, there is but little improvement added to the soil when the crop is removed. It utilizes mineral elements, and the character of its

[1] Cox, Rex W., Fats and Oils, *Minn. Agr. Expt. Sta. Bull.* 376, 1944.

growth tends to leave soil after harvest in such condition that it is subject to erosion if care is not exercised.

Soils.—The ability of the soybean to grow successfully on almost any type of soil has led to the exploitation of fertility in some sections. In general, the crop does best on soil suitable for corn, and this explains in part why the corn belt is so important in soybean production. Since it will grow on soils that are too acid to support the clovers or alfalfa,

FIG. 86.—The soybean leaves the soil in a loose, mellow condition. (*Courtesy of the J. I. Case Company.*)

many farmers have substituted the soybean for these more exacting crops.

Rotation.—The soybean may fit into almost any rotation. Where it is grown as a grain crop, it may be substituted for the oat crop to give a rotation such as corn, soybeans, wheat, clover. Where the crop precedes small grains, it is not necessary to do much work to prepare the soil, as the soybean leaves the soil loose and open. A light disking usually results in an excellent seedbed.

Seeding.—For seed production it is best to grow the crop in rows, which may be cultivated to control weeds. The distance between rows may vary with the fertility of the soil, with the closest spacing on the most fertile soil. On good soils, rows may be 24 to 36 in. apart. Some growers prefer, where weeds are not too much of a menace, to grow the

beans in 6-in. rows seeded with a grain drill. It is believed that, in most cases, a wider spacing is desirable for beans grown for seed. Beans should be seeded early, usually right after the corn is planted and the soil is thoroughly warm.

As the size of seed varies greatly, it is impossible to fix a recommended rate of seeding that will apply to all varieties. Where the beans are grown in spaced rows the average-sized bean requires about 40 to 70 lb. of seed. The ordinary grain drill is very satisfactory for seeding, as one may stop up the drill cups to secure any desired spacing. In Illinois trials,[1] the use of 24-in. rows gave higher yields than a solid seeding in 8-in. rows. Some farmers use the corn planter and split the rows by straddling every other row so as to give a closer spacing. As a rule the beans are dropped about 1 in. apart in the row.

TABLE 41.—COMPARATIVE GRAIN YIELDS OF SOYBEANS CLOSE DRILLED WITH A GRAIN DRILL AND PLANTED IN CULTIVATED ROWS SPACED 35 IN. APART, 14-YEAR AVERAGE

Method of Planting	Bushels per Acre
Drilled	9.0
35-in. rows	15.4

The depth of planting will vary with the soil type and its condition. On heavy soils, a shallower depth is more desirable than on light or sandy soils. The rule should be to plant the seed no deeper than necessary to place it in contact with moist soil. If a rain causes a crust to form before the beans emerge, a light dragging with a smoothing harrow may prove beneficial.

In a comparison of methods of planting soybeans for grain production, Kiesselbach and Lyness[2] reported a decided advantage of growing the beans in cultivated rows over seeding in close-drilled rows.

The drilled beans were seeded at the rate of 95 lb. per acre, while 40 lb. per acre were used in the row-planted plots.

Tillage.—Cultivation should be frequent enough to control weeds. When the plants are small the rotary hoe or harrow may be used to advantage on beans in rows until they are 10 to 12 in. tall. After this, the corn cultivator may be used for later tillage.

Harvesting.—The harvesting is delayed in the fall until the seeds are hard and the leaves have fallen. The crop may be harvested with

[1] BURLISON, W. L., C. A. VAN DOREN, and J. C. HACKLEMAN, Eleven Years of Soybean Investigations, *Ill. Agr. Expt. Sta. Bull.* 462, 1940.

[2] KIESSELBACH, T. A., and W. E. LYNESS, Soybean Production in Nebraska, *Neb. Agr. Expt. Bull.* 339, 1942.

the binder and set in shocks to dry, or it may be harvested directly with the combine. Many farmers prefer this method, delaying harvest until the crop is fully matured. The binder-harvested beans are threshed with a bean separator or an ordinary grain separator operated at a reduced speed to avoid damage to the beans. In some cases it may be necessary to remove concaves to avoid breakage of the beans.

Freshly harvested beans may require further drying before they can be stored in large quantities. It is best to spread them in a well-

FIG. 87.—Many acres of soybeans are harvested with the combine. (*Courtesy of the J. I. Case Company.*)

ventilated place with not more than 4 in. depth of beans. The beans may be stirred occasionally to speed drying. After they are well dried they may be placed in larger bins or sacked.

INSECT AND DISEASE PESTS

As compared with the other grain crops the soybean is fairly free from serious insect pests and diseases. Those of importance are discussed in detail by Morse and Cartter.[1]

Review Questions

1. Why do the corn belt states rank so high in soybean production?
2. Why is the soybean considered a soil-depleting crop?

[1] MORSE, W. J., and J. L. CARTTER, Soybeans: Culture and Varieties, *U.S. Dept. Agr. Farmers' Bull.* 1520, revised 1939.

3. What are the principal uses of the soybean as a grain crop?
4. Why cannot soybean oil be used to replace linseed oil?
5. How can soybean oil be used in paints?
6. What is the cause of "soft pork"?
7. Make a rotation including the soybean as a grain crop.
8. Why is it possible to seed a crop after soybeans with little or no further seedbed preparation?
9. What are the advantages of growing soybeans in rows?
10. How are soybeans for seed commonly harvested in your community?
11. What precautions should be taken in threshing soybeans?
12. What types of soils are best for soybeans?
13. What crops have tended to be replaced by soybeans grown as grain?

References

ARNY, A. C., W. W. BROOKINS, and R. E. HODGSON: Soybeans for Minnesota, *Minn. Agr. Expt. Sta. Bull.* 134, revised 1940.

BURLISON, W. L., C. A. VAN DOREN, and J. C. HACKLEMAN: Eleven Years of Soybean Investigations, *Ill. Agr. Expt. Sta. Bull.* 462, 1940.

DYAS, E. S.: Soybean Production in Iowa, *Iowa Agr. Expt. Sta. Bull.* P30 (new series), 1941.

ETHERIDGE, W. C., C. A. HELM, and B. M. KING: A Classification of Soybeans, *Mo. Agr. Expt. Sta. Research Bull.* 131, 1929.

HUTCHESON, T. B., T. K. WOLFE, and M. S. KIPPS: "The Production of Field Crops," McGraw-Hill Book Company, Inc., New York, 1936.

JOHNSON, H. W., and B. KOEHLER: Soybean Diseases and Their Control, *U.S. Dept. Agr. Farmers' Bull.* 1937, 1943.

KING, B. M., and D. I. ALLEN: Soybean Production in Missouri, *Mo. Agr. Expt. Sta. Bull.* 445, 1942.

MORSE, W. J., and J. L. CARTTER: Improvement in Soybeans, *U.S. Dept. Agr., Yearbook of Agriculture,* 1937.

PARK, J. B., and J. A. SLIPHER: The Soybean: Its Place in a Farming System, *Ohio Agr. Ext. Bull.* 199, 1939.

PIPER, C. V., and W. J. MORSE: "The Soybean," McGraw-Hill Book Company, Inc., New York, 1923.

RATHER, H. C.: "Field Crops," McGraw-Hill Book Company, Inc., New York, 1942.

SEARS, O. H.: Soybeans: Their Effect on Soil Productivity, *Ill. Agr. Expt. Sta. Bull.* 456, 1939.

ZAHNLEY, J. W.: Soybean Production in Kansas, *Kans. Agr. Expt. Sta. Bull.* 306, 1942.

CHAPTER XVII

CORN GROWING

Corn, the leader of grains in the United States, is an American crop that ranks first in total average acreage and production among the various agricultural crops. Undoubtedly more farmers grow some corn than is true for any other crop. Jenkins[1] says,

> Of all the things that are characteristic of America, corn is perhaps the most characteristic. The discovery of America was the discovery of corn. There was a corn civilization in this country before the coming of Columbus, especially among the Aztecs, the Mayas, and the Incas and in a very real sense there still is a corn civilization. The important part played by corn in the early civilization is indicated by the numerous relics.

The early settlers who came to America learned from the Indians the methods of growing corn and depended upon it for much of their food supply. With the development of our country and the introduction of other agricultural crops, particularly wheat, corn ceased to be a primary food material and shifted to our most important feed for livestock.

BOTANICAL CLASSIFICATION

Although very different in appearance from wheat, oats, and barley, corn like these plants is a member of the great grass family. The accepted scientific name of corn is *Zea mays*, given to the plant by the great Swedish taxonomist Linnaeus. The word *Zea* is from the Greek word for cereal, which according to Weatherwax,[2] in turn, was derived from the verb meaning "to live."

In recent years, evidence has been presented to show that the old system of classifying the various types of corn, as was done by Sturtevant, is no longer tenable.

Hayes and Immer[3] present an excellent discussion of the modern viewpoint.

[1] Jenkins, Merle T., Corn Improvement, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

[2] Weatherwax, Paul, "The Story of the Maize Plant," University of Chicago Press, Chicago, 1923.

[3] Hayes, H. K., and F. R. Immer, "Methods of Plant Breeding," McGraw-Hill Book Company, Inc., New York, 1942.

Zea mays L. has a normal chromosome complement of 10 pairs. Each of the subspecies described by Sturtevant normally has 10 pairs of chromosomes, and in several cases the differences are dependent upon a single factor pair. It seems, therefore, more proper to consider these as agronomic groups rather than as subspecies. On this basis, the following groups are worthy of consideration:

Dent corn
Flint corn
Popcorn
Sweet corn
Flour corn
Pod corn
Waxy corn

Dent Corn.—As the name indicates, the kernels are dented at maturity, a condition that varies within different varieties from nearly smooth indentation to a deep or rough indentation. With the added emphasis upon maturity there has been a definite trend toward corn with less pronounced indentation of the kernel. The indentation is the result of the shrinkage of the soft or crown starch as the kernel dries at maturity.

In the dent varieties, kernel color varies from white to yellow and red with by far the greater percentage yellow in color. Cob color varies from red to white with red cob color being the most common.

Commonly the plant is relatively tall, especially in the so-called *fodder* or *silage* varieties, and tends to sucker moderately. The improved hybrid varieties developed for grain production are heavier producers than old open-pollinated types from which they were developed.

Flint Corn.—The kernel is very hard, and farmers have long referred to this corn as *flint*. The entire crown of the grain is covered by a layer of hard or horny starch which does not shrink on maturity as is true of the dent types. The kernels of well-matured corn are so hard that animals frequently experience difficulty in eating the grain. This is the type of corn that was grown by the Indians in the more northern areas since many of the varieties were early maturing. Even today in those areas where the season is too short for the growing of the dent varieties, and in parts of the South, the flint corns are of considerable importance. In some parts of the world, as in Argentina, late-maturing flints are of great importance.

The color of the flint grains ranges from a pearly white to yellow, blues, reds, and color combinations of nearly all shades of the listed

primary colors. Most of the varieties have eight-rowed ears, so that the ears are small in circumference. Many varieties have short ears, while others are extremely long.

The plant is rather short, leafy, and tends to sucker freely. Most varieties mature rather quickly as compared with the dent corns and so can be grown farther north and in higher latitudes than the dents. For the most part the flints grown in the United States are not greatly different from those grown by the Indians many years ago, since they have not received the attention of the breeders accorded to the more important dent types.

Popcorn.—The popcorns are like the flints in kernel characteristics in that they have a large percentage of horny starch. They are peculiar in that when they are heated the pressure built up within the kernel suddenly results in an explosion and the grain is literally turned inside out. The plant is grown almost entirely as a confection-like food and it is eaten by most consumers as a supplement to the regular diet.

The kernels vary in color from white and yellow to deep purple. The plant is usually short and tends to develop many secondary stalks, or suckers.

Sweet Corn.—This type of corn derives its name from the sweet flavor of the green ears. It is a very important food crop, being consumed in the immature or green stage. Nearly all sweet corn is either white or yellow in color. In some varieties the grains are waxlike in character and become greatly wrinkled upon maturity. The plant is very leafy, of medium height, and tends to sucker rather freely.

Flour Corn.—The flour corn grown in America is of relatively little importance, being grown to a limited extent. It is a favorite of the Indians of the Southwest, since the large soft grains are easily ground into a nutritious meal.

All colors of grains are found, but white and blue are probably the most common. The plants are rather leafy with a tendency to sucker freely.

Pod Corn.—The pod corns are characterized by having each kernel enclosed within a pod or husk. Any one of the previously listed groups may occur in the pod form. Except for its interest to the student of genetics pod corn is of no importance.

Waxy Corn.—The endosperm is of a waxy nature, and the elaborated carbohydrates are in a form different from that found in the starchy varieties.

An excellent description of the corn plant has been prepared by

Tapley, Enzie, and Van Eseltine.[1] Their discussion has been used freely below.

The corn plant is a highly specialized grass with many of the characters of other grasses, particularly the fibrous root system, the parallel-veined leaves, and the typical floral structures.

The primary roots of the germinating seed are soon followed by the secondary roots from the first node of the stem. These in turn are followed by larger, more extensive roots which arise from successively higher nodes. As the plant grows it develops the so-called *brace* or *prop* roots which commonly arise from the first few nodes above the soil level.

The stem is divided into nodes and internodes with the leaves arising from the upper end of each internode. At the base of each node is bud tissue which may or may not give rise to a branch. The internodes are solid, not hollow as in many of the grasses, and are filled with pith which carries the scattered fibrovascular bundles. Since each node constitutes a growing point, the plant elongates very rapidly during its period of most rapid growth. The nodes are close together at the base and are progressively farther apart as the tip of the plant is approached. This gives rigidity at the base and allows for flexibility in the wind at the upper part.

FIG. 88.—The pistillate or female inflorescence of corn. *A*, the young ear shoot with husks removed, showing the attachment of the silks; *B*, an enlarged section through a group of ovules, showing more detailed structure. (*Courtesy of G. F. Sprague, Iowa Agricultural Experiment Station.*)

The inflorescences of the corn plant are separated, with the male flowers on the terminal part of the stalk and the female flowers lower down on a developed bud that arises from a node. The male flowers are commonly referred to as the *tassel* and the female flowers as the *rudi-*

[1] TAPLEY, W. T., W. D. ENZIE, and G. P. VAN ESELTINE, The Vegetables of New York, Vol. 1, Part III, Sweet Corn Report, *N. Y. Agr. Expt. Sta.*, 1934.

mentary ear. The staminate flowers in the tassel produce the pollen, which is carried by gravity and air movements to the silks of the pistillate flowers. The silk corresponds to the style of the simple flower.

The spikelets of the staminate flowers are much like those of wheat and oats, except that they possess only the pollen-bearing organs.

The styles (silks) of the female flowers generally are receptive to pollen for about 2 weeks after they emerge from the husks. The pollen fall from the tassel lasts 2 or 3 days to several days, since the upper branches mature before the lower ones, the tip flowers before the base flowers, and the lower florets of each spikelet before the upper ones.

Each kernel of corn is a fruit, with the entire ear classed a compound fruit. The kernels are of great importance in the classification of corn varieties, since their very significant characters are a basis of differentiation.

By the nature of its floral parts the corn plant normally cross-pollinates to produce a very heterozygous condition. In the discussion of the improvement of grain crops in Chap. XXIII, further consideration is given to this subject.

AGRONOMIC CLASSIFICATION

The agronomic classification of dent and flint corns in general is related to the use made of the crop. Frequently the uses are overlapping, and distinct differences are not always evident between groupings. Many of the varieties are such that they lend themselves to more than one use, while others are specifically best suited to a special purpose. The principal classes on an agronomic basis are the following:

Corn for grain
Silage
Fodder

Grain.—By far the largest acreage of corn is grown for harvesting the ear corn either for later feeding or for marketing as a cash crop. It is for the improvement of this type of corn that most of the corn breeding has been done. The most satisfactory variety is the one capable of producing the greatest yield of sound corn.

Silage.—In the dairy sections of the country the production of corn for silage is very important. In many cases the same variety is used for silage as that which is grown for ear corn. In other cases, particularly in the New England states, emphasis has been placed upon the development of a type of corn that grows very tall and yields a large

tonnage. White *et al.*,[1] in Connecticut silage studies, found that on farms where the price of milk was reasonably high and available corn land was limited, it was advisable to grow heavy-yielding late-maturing varieties of corn. In the corn belt, however, the more mature types are preferred, and usually corn is not ensiled before it is in the early dent stage. In years when the crop fails to mature before frost, it is common to preserve it by placing it in the silo regardless of the maturity.

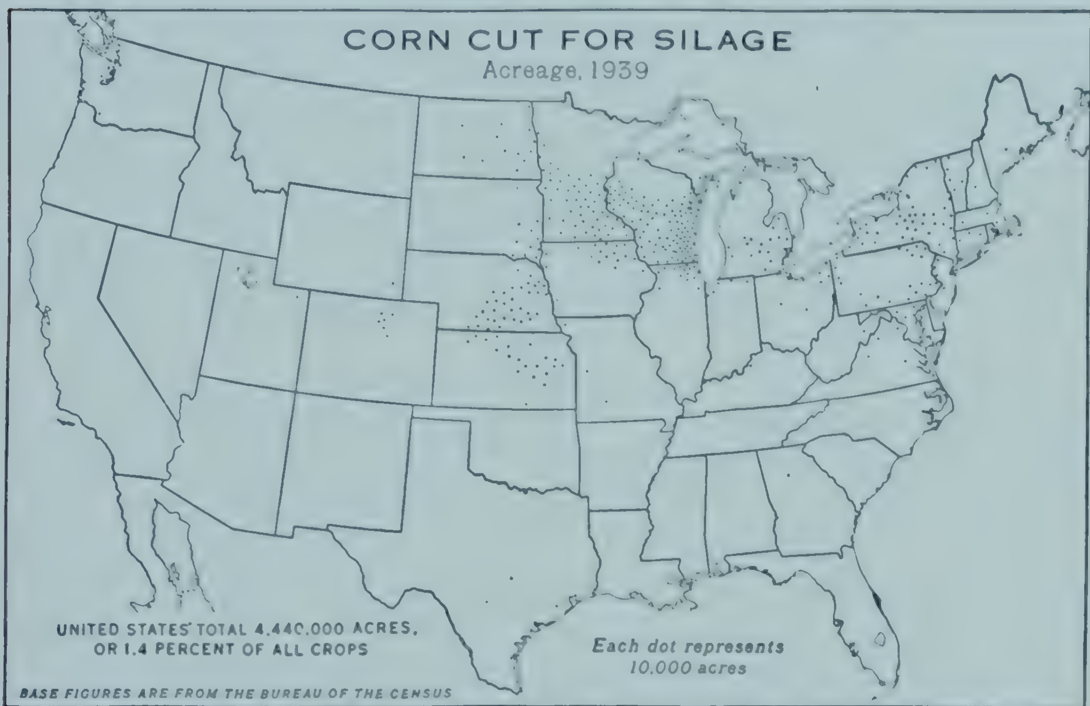


FIG. 89.—Acreage of corn cut for silage in the United States. (*Courtesy of the Bureau of Agricultural Economics, U.S. Department of Agriculture.*)

Frequently this means the difference between valuable feed and a nearly total loss.

Fodder Corn.—In many of the corn-producing areas, especially when livestock are fed through the winter, it is a common practice to harvest the corn with a binder, sled cutter, or other means and shock it for later feeding. Some farmers feed the entire plant including the ears to the livestock, particularly cattle, while others husk the ears from the bundles and feed the remaining stover.

MARKET CLASSIFICATION

Since so much of the corn crop is marketed as shelled grain it is important that one engaged in its production understand some of the

[1] WHITE, G. C., L. M. CHAPMAN, W. L. SLATE, JR., and B. A. BROWN, A Comparison of Early, Medium, and Late Maturing Varieties of Silage Corn for Milk Production, *Storrs Agr. Expt. Sta. Bull.* 121, 1924.

market requirements for the cereal grains. The government has established standards for shelled corn, and these are applied to all shipments that pass through terminal markets. As with the other grains, the inspection is made by state employees who are licensed by the Federal government.

The Federal standards define corn as any grain that consists of 50 per cent or more of shelled corn of the dent or flint varieties, and it may not contain more than 10 per cent of other grains for which standards have been established under the provisions of the United States Grain Standards Act.

There are three market classes of corn based upon color of the kernel: Yellow Corn, White Corn, and Mixed Corn. Yellow Corn includes all varieties of yellow and máy not include by weight more than 5 per cent of corn of colors other than yellow. A slight tinge of red on the kernels otherwise yellow shall not affect their classification as Yellow Corn.

White Corn is held to a somewhat higher standard than yellow. To grade White Corn the sample must be at least 98 per cent white. A slight tinge of light straw or of pink on the kernels of corn otherwise white shall not prevent their being classed as White Corn.

Mixed Corn shall include all lots that do not meet the color requirements of the yellow or white classes. So-called white-capped-yellow varieties and red corns are classified as Mixed.

Flint corn must be 95 per cent or more of corn of the flint varieties. It is graded the same as dent corn except that the word "Flint" is added to and made a part of the grade designation as Yellow Flint Corn or White Flint Corn.

There are five numerical grades and Sample Grade based upon the factors of test weight per bushel, percentage of moisture, cracked corn and foreign materials, and damaged kernels. Each of the factors except cracked corn and foreign material is self-explanatory. Cracked corn and foreign material includes kernels and pieces of corn that pass through a No. 12 sieve and all matter other than corn which remains on such sieve after screening.

Corn that is musty, sour, heating, or hot is placed in Sample Grade. In many parts of the corn-producing area, the presence of excess moisture at the time of marketing is the principal factor that operates in determining the grade of most corn that is marketed. As would be expected, total damage and heat damage are directly related to the presence of excess moisture during storage of the harvested corn. As severe discounts result when corn reaches the market in poor condition,

it is advisable insofar as possible to choose varieties that are capable of maturing within the latitude where they are grown.

USES OF CORN

By far the greater part of the corn crop is fed to livestock on the farm. The area of greatest concentration of corn production coincides rather closely with the region where most hogs are raised. No other feed is so suitable as corn for the fattening of hogs and cattle, and when combined with supplementary protein feeds economical and profitable gains usually result from its feeding. Jenkins[1] estimates that about 80 per cent of the corn crop is fed to stock on farms where it is grown.

TABLE 42.—APPROXIMATE CHEMICAL COMPOSITION OF CORN, IN PER CENT

	Water	Protein	Ether extract	Crude fiber	Carbohydrates other than crude fiber	Ash
Maximum	12.32	11.55	5.06	2.00	75.07	1.55
Minimum	9.58	8.58	2.94	1.00	68.97	1.19
Mean	10.93	9.88	4.17	1.71	71.95	1.36

When America was discovered, nearly all the corn being produced was used for human food. Even today in parts of Central America and Mexico corn forms the principle article of the human diet. In the United States, however, relatively little of the entire crop enters into human food, probably somewhat less than 5 per cent.

Corn is essentially carbonaceous in composition. The principal parts of the kernel are the hull or seed coat, the starch-rich endosperm, and the fat-rich embryo. The endosperm consists of the aleurone layer of cells rich in protein and the soft and horny starch. On an average, about 80 per cent of the endosperm is starch and protein. The embryo is rich in oil but also contains about 25 per cent carbohydrates and a small percentage of protein. Table 42, from Prescott and Proctor,[2] illustrates the average composition of corn.

Most corn is fed to livestock in its original form, usually to hogs on the ear and commonly to other classes of animals, such as steers and sheep, when it is shelled. Frequently the grain is coarsely ground or

[1] JENKINS, M. T., Corn Improvement, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

[2] PRESCOTT, S. C., and B. E. PROCTOR, "Food Technology," McGraw-Hill Book Company, Inc., New York, 1937.

cracked to make it easier for the animals to consume the grain. Where corn is fed to cattle in the feed lot, it is common to permit hogs to follow the cattle to recover the undigested corn that passes through the digestive systems of the cattle. Many prepared feeds carry a percentage of ground corn in their composition, but such use involves only a small quantity in relation to total production.

Humans usually eat corn either as corn meal or as hominy. In corn meal the seed coats and germs are separated and the remaining endosperm is ground into meal. In spite of the fact that yellow meal is a better food because it contains vitamin A, the average consumer prefers white corn meal and is willing to pay a premium to obtain it. Hominy is prepared by removing the seed coats with a lye solution and then cooking the remaining material which includes both the endosperm and the embryo. Hominy is a nutritious food, but the greater part of the American people consume relatively little hominy during a year. A small quantity of corn is used in the preparation of corn flakes, which are made by rolling the endosperm into thin flakes, and roasted to a golden brown.

During recent years increased quantities of corn have been used in the manufacture of corn oil. The American housewife does not, as a rule, like oils for cooking and prefers the solid fats. Some of the corn oil is used in the manufacture of shortening compounds, salad oils, soaps, varnishes, paints, and similar products. The by-product of the oil extraction is a cake that is valuable as a livestock feed.

Cornstarch, an almost universal foodstuff in the average American home, is made from the corn grain after the oil has been removed. The product is widely used in the making of puddings and in the manufacture of candies and certain types of industrial products; an important by-product is gluten feed, which is separated from the starch. Gluten feed contains a large percentage of protein and makes a highly prized feed.

Sugar may be made from cornstarch by heating it with dilute hydrochloric acid to convert the starch into dextrins, sirup, and sugar, a mixture of dextrose and maltose. The final step in hydrolysis gives the true corn sugar, or dextrose, a six-carbon sugar or monosaccharide.

Corn sirup is widely used as a table spread, in the manufacture of certain confections, and in the preserving of fruit products.

Corn sugar is used in the baking industry, in confections, and in certain types of food products. Being a monosaccharide, it is not so sweet as sucrose, a disaccharide with which it is sometimes combined in food processing.

During recent years there has been increased interest in the manufacture of ethyl alcohol from corn. It appears likely that the making of alcohol from corn may increase as time passes and there is a greater demand for the alcohol.

Waxy corn, once looked upon as a genetic curiosity, can be used to replace tapioca and to serve in the manufacture of adhesives. The variety Waxy Iowa Hybrid 939, developed cooperatively by the Bureau of Plant Industry and the Iowa Agricultural Experiment Station, gives considerable promise. In tests it has proved to be a satisfactory substitute for tapioca, and many people have been unable to distinguish between commercial tapioca and the waxy corn product when the two kinds were made into puddings. Since America's annual imports of tapioca have averaged about 350,000,000 lb., with most of the supply coming from the Dutch East Indies, it is apparent that waxy corn offers real possibilities.

Kiesselbach,[1] reporting on waxy corn, states that it appears to be especially suitable to replace the tapioca starch made from the imported cassava root since it can be milled with the same equipment already available for ordinary corn.

In eastern Nebraska field trials for 3 years, several waxy varieties were compared with open-pollinated and hybrid corns. Iowax 1, the most productive waxy variety, yielded about 4 per cent less than Iowa 939, to which it is very similar except for the waxy factors, and 15 per cent less than U.S. 13 under conditions where the latter hybrid was well suited. The author indicates that Iowax 1 would more nearly approach the yield of U.S. 13 if field stands were increased about 20 per cent. Further, to make the production of waxy corn profitable, it appears desirable that a premium be paid over the prices paid for ordinary corn.

Cornstalks and stover provide valuable roughage either in the form of silage, the standing stalks in the field being fed as fodder corn, or in the use of the shredded product. The standing stalks after husking provide relatively little feed, and in fields where a mechanical husker has been used there is little material that can be salvaged. The shredder is used to but a limited extent. Where used it is common to blow the stover into the barn and feed it during the winter with the rejected material being used as bedding, a use to which it is not nearly so well suited as grain straw.

Much work has been done to develop the by-products of corn. The

[1] Kiesselbach, T. A., Character, Field Performance, and Commercial Production of Waxy Corn, *J. Am. Soc. Agron.*, **36**:668–682, 1944.

stalks when properly treated yield a material that may be used for paper, cardboard, and insulation. The cobs have been used to produce plastics, acetic acid, methanol, tar, charcoal, and furfural.

A very large industry has been developed in Missouri, where corncobs are used to manufacture pipes. Corncob pipes are widely distributed and provide a profitable outlet for relatively large quantities of a by-product that otherwise is of little or no value.

THE PLACE OF CORN ON THE FARM

Because of its great importance it appears desirable to consider the place of corn in the farm setup.

Every good farm rotation should if possible include at least one cultivated crop, for it is nearly impossible otherwise to control the weeds that infest every farm. Where corn can be grown successfully, it is the ranking intertilled crop. For the common rotation of corn, small grain, clover, it is especially well suited. Many farmers prepare the seedbed for the small grain with a disk with a minimum of labor and expense. In some sections it is common to seed winter wheat or rye in the cornfield after the last cultivation. The corn is harvested, and the new crop is given full occupancy of the land.

The labor required for corn fits well into the labor distribution. Planting comes after the small grains are seeded, and most of the tillage is done during the time when the small grains require no attention. The principal objection of many farmers is that the making of hay often occurs at the same time as the corn needs cultivation. This conflict is particularly true with the first cutting of alfalfa.

After the corn is laid by it requires little or no attention, and the farmer is able to care for the harvest of other crops, and do his threshing and fall plowing of grain stubble fields and meadows. Following frost and maturity of the corn, with a favorable season the other fall work is taken care of and he can proceed to harvest the corn crop. Where silage is made or the corn is cut for fodder, there may be a conflict with other farm operations. With power farming so general, however, relatively little time is required to care for these operations. On the whole, corn fits well into the labor distribution on the average farm.

GENERAL REQUIREMENTS FOR CORN

While corn is grown successfully in nearly every part of the United States, it probably finds conditions most favorable for its economical production in the corn belt, which roughly includes the states of Iowa,

Illinois, Minnesota, Wisconsin, Nebraska, Kansas, Missouri, Ohio, Indiana, and South Dakota. With Iowa as a center point, the principal corn sections are those states which are near Iowa. The general requirements for corn may be listed as follows: (1) growing season of frost-free days long enough to mature the crop; (2) adequate rainfall, (3) productive soil, (4) adapted variety, (5) good seedbed, (6) good stand, and (7) thorough tillage.

FIG. 90.—The yields in many cornfields are reduced greatly by the numerous weed plants which compete with the corn plants for water and nutrients.

Growing Season.—On an average, most dent corn varieties require a frost-free period of 90 days or more to mature a crop. Some varieties mature in less than 90 days, but most require 110 to 130 days. The development of earlier maturing hybrids has done much to push the corn belt to the north. Many farmers attempt to grow varieties that are unsuited to their season. Early seeding is desirable so as to make the best use of the season, but experience has shown that it is best not to plant corn until the soil is warm. The later planted corn frequently germinates better and gives a more perfect stand than that planted in cold soil. Of course it must be recognized that early planting is desirable provided that the soil is warm. Periods of great heat are not necessary for rapid growth as some have believed, but unseasonably cool nights do tend to retard the rate of growth and may delay the maturity.

Adequate Rainfall.—It is difficult to set a figure as a minimum of precipitation but, except under irrigation, it is probable that little corn is produced in areas where the rainfall averages less than 20 to 25 in. Of course distribution of rainfall is of great importance, and the corn plant requires much water during the growing months. Probably August is the most critical month in most sections, as this is a period of high evaporation and rapid growth of the plant, with very high requirements.

Productive Soil.—Corn is a heavy feeding plant and does best on fertile soils that are adequately supplied with nitrogen and phosphorus.

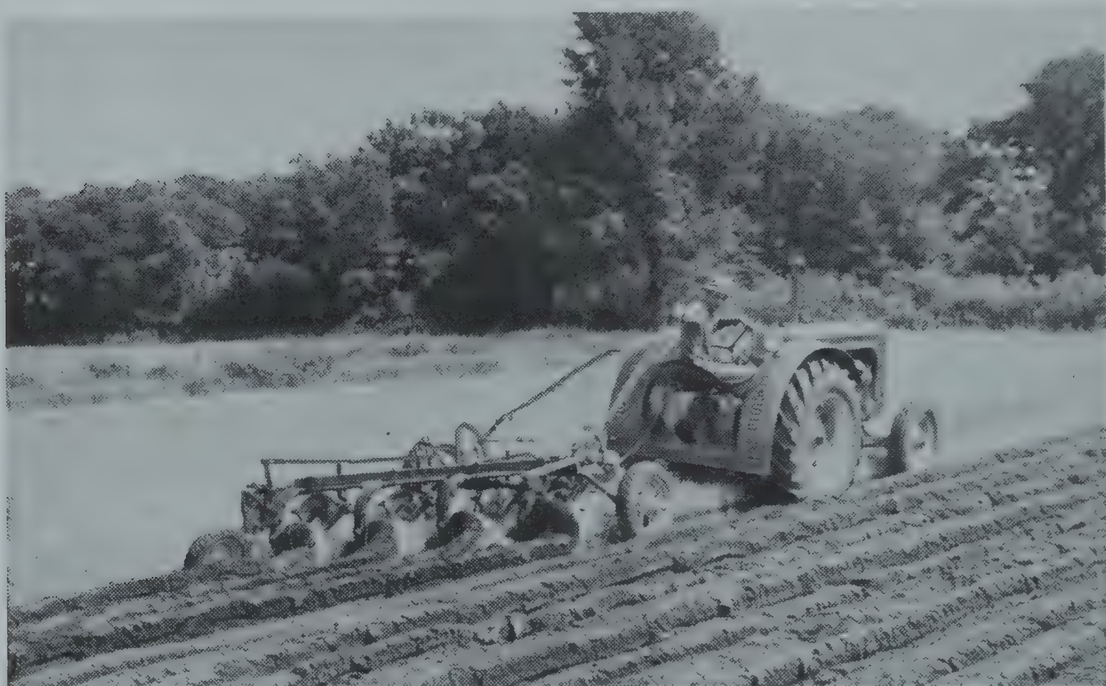


Fig. 91.—Many farmers plant corn after a sod crop. (*Courtesy of the J. I. Case Company.*)

Other elements are essential, but these two are especially likely to result in low yields if not present in adequate amounts. Sandy soils are very suitable for corn if they are supplied with fertility and moisture, and some of the highest yields of corn are obtained on the sandy soils of the river-bottom lands of the Mississippi and its tributaries. While one can grow a good crop of rye on average soil, he needs better than average for corn. Most farmers give corn the choice place in the rotation and apply the barnyard manure and commercial fertilizers so as to give the crop the best opportunity, as experience has proved this to be a desirable practice on most corn farms. If the soil is not productive, it is much better to grow some crop other than corn.

Adapted Variety.—With the host of good varieties available it is imperative that a superior variety be chosen. Particular attention

should be be given to the length of time required for maturity so as to make certain that an unadapted type is not selected. Where one is not certain as to the varieties best suited to his conditions, he should check with his own state agricultural experiment station. Only in this way can he be certain of securing varieties that are most desirable. Every purchase of so-called *cheap* seed is almost certain to prove expensive in the end. One should proceed on the basis that on an average the highest priced seed is the best and that if economies are to be made they should be made in other areas of the project. It is assumed that hybrid varieties of known performance will be used in preference to open-pollinated types. The farmer should look to his own state experiment station for varietal recommendations and choose only those which have been proved adapted to his section. The significance of hybrid varieties is considered in detail in Chap. XXIII.

A Good Seedbed.—A good principle to follow is to keep in mind that a little extra time spent in seedbed preparation saves much time later in the season; especially is this true in the control of weeds. Thorough plowing with a well-tilled, compact surface is desirable even though planting must be delayed a few days. Often the corn that is planted on a well-prepared seedbed will overtake and pass a crop that was seeded earlier in a poorly prepared field. In areas where erosion is not a problem, a prime advantage of fall plowing is that it frequently makes it possible to prepare the soil for planting a few days earlier and thus favor early seeding, which is of great importance in most of the important corn-growing states.

A Good Stand.—Every corn grower knows that without a good stand he cannot expect to get maximum yields. It is important that the seed be high in percentage germination and that a properly operating planter be used. A worn or defective planter may easily lose the grower in one season the money required to purchase a new machine. A few weeks before the planter is needed, it should be checked for accuracy of drop. With the use of hybrid corn and greater attention to the grading of kernels as to size, one must be certain that the planter plates are proper for the grade of kernels. If this is neglected, poor stands are likely to occur as a result of uneven planting. With the best soil and a favorable season a poor crop may result from carelessness in doing the things which favor a good stand.

Thorough Tillage.—In spite of the best rotations and seedbed preparations, weeds are certain to be a menace to the corn crop. Thorough cultivation must be the rule if one is to hold these weeds in check. Often the spike-tooth harrow or a weeder may be used to advantage in destroy-

ing weeds while the corn is small. With the advent of power farming there has been some tendency to cultivate less often as the farmer has increased his acreage. It is probable that many farmers have cultivated their fields more often than necessary, but they are the exception. At best many weeds will grow after the corn is laid by, so it is imperative that a thorough job be done while possible. Early tillage should be deep and close to the plants; later tillage should be shallow to avoid injurious root pruning.

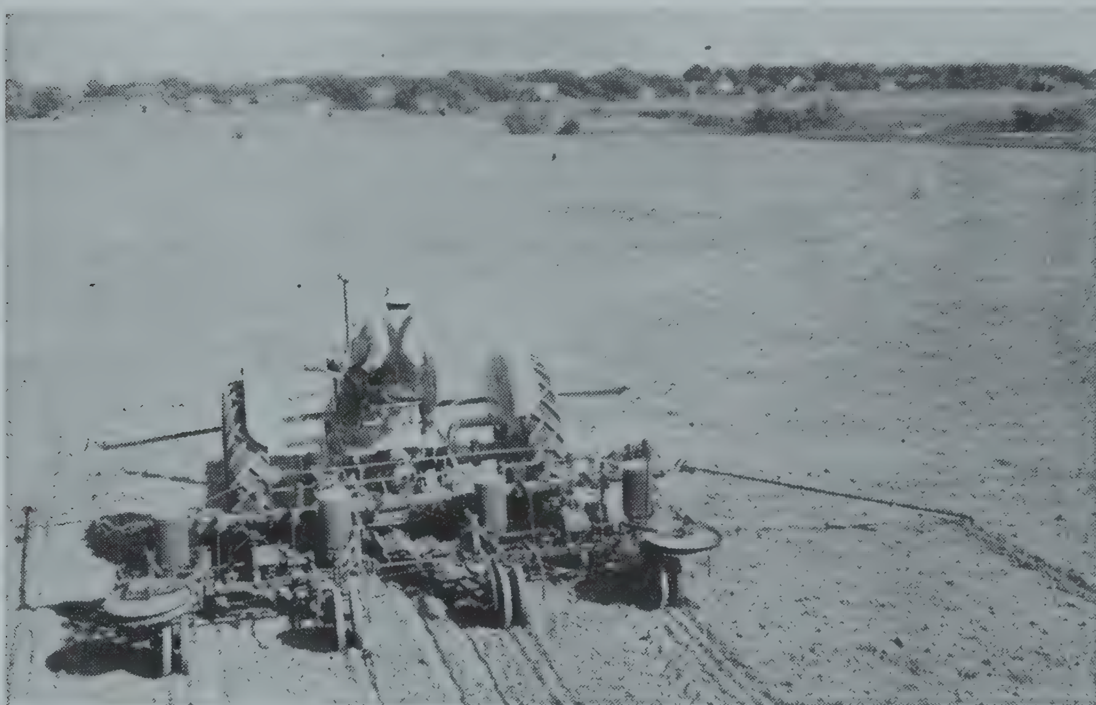


FIG. 92.—The four-row corn planter makes rapid planting possible. (*Courtesy of the J. I. Case Company.*)

CORN CULTURE

In Chap. V, the general problems of culture have been considered for the corn crop as a whole. Here more specific problems will be given consideration.

In general, corn is planted by two systems; it is checked or drilled. In checking the hills are spaced so as to permit cross-cultivation. This plan is most general over the corn belt as it permits much better control of weeds. Many farmers drill their first crop of corn following a pasture or meadow crop on the assumption that weeds will not be such a factor and that they can get more plants to an acre by drilling and thus obtain a higher yield. As a rule when corn is drilled the kernels are dropped 10 to 14 in. apart, with an average distance between the rows of 3 ft. and 6 in. The common practice in checking corn has been to

space the checked hills 3 ft. and 6 in. apart so that the distances were the same each way. In recent years, on fertile soil, many farmers have decreased the distance between hills and rows so as to get more plants per acre. Modern corn planters are readily adjusted to give wide or narrow spacings. Where the distance between the rows is reduced, similar adjustments must be made in the tillage machinery. It must be remembered that only highly fertile soils will permit closer spacing, as too close spacing on land of average or low fertility will result in reduced yields of lower quality grains.

In general, the Illinois Agricultural Experiment Station[1] found the best rates to be as follows: northern Illinois, three kernels per hill in rows 3 ft. apart; central Illinois fertile soils, three kernels per hill in rows 3.3 ft. apart and on less fertile soils two kernels per hill in rows 3 ft. apart. In northern Iowa five kernels per hill gave the best yield, in south central Iowa four kernels, and in the southern one-fourth three kernels. In Minnesota, three or four kernels per hill in 44-in. check rows gave the best yields. Ohio reported the best yields from four kernels per hill in rows 3.5 ft. apart. In general it may be said that rates and distances vary directly with the productivity of the soil and to some extent with the use to be made of the crop. Those farmers who expect to use the crop for silage often plant at a heavier than normal rate. On sandy soils where moisture supplies may be inadequate rates should be reduced to avoid serious drought damage.

Usually corn is planted just deep enough to place the seeds in moist soil. On drier soils, particularly sandy types, the depth must be increased, although it is seldom advisable to plant corn more than 3 in. deep at the most. It should be remembered that the shallower the planting that gets the seed in contact with moist soil, the more rapid will be the emergence and the greater the chances for securing a good stand. In cold wet soils deep planting may result in poor emergence.

In many parts of the South and the Southwest the lister is used instead of the surface planter. Others use the furrow-opener planter, which supposedly combines the advantages of listing and level planting, although the furrow-opener method is not so widely used as the lister. This has the advantage of providing better moisture conditions and somewhat better control of weeds.

No definite figures can be given as to the amount of corn required for an acre, as this varies with the size of the kernel and the width of the space between hills and rows. In general, 1 bu. of corn will plant 6 to 9 acres. Naturally if small flat kernels are used, the bushel will plant

[1] Richey, F. D., Corn Culture, *U.S. Dept. Agr. Farmers' Bull.* 1714, 1933.

a greater acreage than if the grade *large flats* are purchased. The small amount of seed required emphasizes again the lack of wisdom in the false economy exercised when one purchases questionable or bargain seed.

FIG. 93.—Tillage is primarily for the control of weeds. (*Courtesy of the Allis-Chalmers Company.*)

Tillage has been discussed, and it may be summarized by stating that it must be frequent enough to control weeds and in some cases to break the hard crust which tends to form on many soils following a heavy rain.

Review Questions

1. Botanically, how is corn related to wheat?
2. Name the species of corn.
3. Which species are grown in your community?
4. What is fodder? Stover?
5. How does horny differ from soft starch?
6. Why does popcorn pop?
7. Where is most flour corn grown?
8. What is waxy corn?
9. Of what economic value is waxy corn?
10. What factors should one consider in determining whether or not to build a silo?
11. When would it be advisable to cut corn and feed it as fodder?
12. Name the market classes of corn.
13. What are the principal factors in grading corn?
14. List the principal uses of corn.

15. Why is corn such a desirable feed for fattening livestock?
16. How does corn sugar differ from cane sugar?
17. Make up the general requirements for corn growing.
18. Make up a type rotation including corn.
19. Why is rainfall distribution so important in corn growing?
20. Give the essential characteristics of a good seedbed for corn.
21. About how many acres can be planted from 1 bu. of corn?
22. Under what conditions would you advise the drilling of corn?
23. What manufactured corn products are sold for livestock feeding in your community?
24. Why is not more corn oil used in cooking?
25. Why is not corn oil a good substitute for linseed oil in the making of paints?

References

HUGHES, H. D., and E. R. HENSON: "Crop Production," The Macmillan Company, New York, 1930.

KIESSELBACH, T. A., A. ANDERSON, and W. E. LYNESS: Cultural Practices in Corn Production, *Neb. Agr. Expt. Sta. Bull.* 293, 1935.

KOEHLER, BENJAMIN, G. H. DUNGAN, and W. L. BURLISON: Maturity of Seed Corn in Relation to Yielding Ability and Disease Infection, *J. Am. Soc. Agron.*, **26**: 262–274, 1934.

LEONARD, W. H., J. F. BRANDON, and J. J. CURTIS: Corn Production in Colorado, *Colo. Agr. Expt. Sta. Bull.* 463, 1940.

MANGELSDORF, P. C., and R. G. REEVES: The Origin of Indian Corn and Its Relatives, *Tex. Agr. Expt. Sta. Bull.* 574, 1939.

OLSON, P. J., and H. L. WALSTER: Earliness in Northern Corn as Affected by Phosphate Fertilizers, Manure, and Other Soil Treatments, *J. Am. Soc. Agron.*, **26**: 205–213, 1934.

RATHER, H. C.: "Field Crops," McGraw-Hill Book Company, Inc., New York, 1942.

RICHEY, F. D.: Corn Culture, *U.S. Dept. Agr. Farmers' Bull.* 1714, 1933.

SCARSETH, G. D., H. L. COOK, B. A. KRANTZ, and A. J. OHLROGGE: How to Fertilize Corn Effectively in Indiana, *Purdue Univ. Agr. Expt. Sta. Bull.* 482, 1943.

SHEDD, C. K.: Machinery for Growing Corn, *U.S. Dept. Agr. Circ.* 592, 1940.

WALLACE, H. A., and E. N. BRESSMAN: "Corn and Corn Growing," 4th ed., revised, John Wiley & Sons, Inc., New York, 1937.

WIMER, D. C., and M. B. HARLAND: The Cultivation of Corn, *Ill. Agr. Expt. Sta. Bull.* 259, 1925 (reprinted 1938).

CHAPTER XVIII

CORN HARVESTING AND STORAGE

Probably no other grain crop presents a greater range of varied problems relative to its harvest, storage, and utilization as the corn crop. Grown in many areas where it is ever a struggle to mature the crop before the coming of freezing weather, corn is in a class of its own. Many a farmer, having spent much labor on an excellent crop of corn, finds that an early frost or a wet, abnormal season has necessitated a change in plans, and must utilize his crop so as to salvage the immature corn or else suffer a nearly complete loss of his season's efforts.

METHODS OF HARVESTING

The principal methods of harvesting corn are (1) husking the ears from the standing stalks, (2) cutting the crop and shocking as fodder corn, (3) storing the harvested plants as silage, and (4) the use of hogging-off practices. Of course small amounts are harvested by other means, such as use as soilage and the topping of the plants, but these are not of great importance.

Husking.—Probably 85 per cent of the corn crop is normally harvested from the standing stalks for storage in cribs to dry for later feeding or marketing. With the great increase in mechanical huskers, farmers have been able to handle many more acres and fewer and fewer acres are harvested by hand. Shedd and Collins[1] state that, when allowance is made for all miscellaneous harvesting labor and favorable weather, the labor required for harvesting corn yielding 60 to 70 bu. per acre with a two-row picker will average about 1½ to 2 man-hours per acre with the best equipment, which is approximately one-fourth of the labor required for husking. The result of this mechanization has been that generally the crop is harvested much more rapidly and earlier in the season than was true years ago.

With normally cool fall weather it is usually safe to crib corn when

[1] Shedd, C. K., and E. V. Collins, Mechanizing the Corn Harvest, *U.S. Dept. Agr. Farmers' Bull.* 1816, 1938.

the moisture contents of the ears has fallen to 25 per cent. However, if the weather is mild and damp, spoilage may occur when the corn is placed in large heaps. Care must be exercised to provide for adequate ventilation and the avoidance of hybrid seed corn as produced on the average farm.

The increased use of the mechanical husker has resulted in a loss of the greater part of the cornstalk, which when husked by hand provides considerable roughage for livestock, particularly cattle. This dis-

FIG. 94.—The two-row mechanical harvester has reduced the time required to harvest corn. (*Courtesy of the J. I. Case Company.*)

advantage, however, is more than offset by the saving in labor and time which are factors of extreme importance in most corn-producing areas. The corn farmer in the areas where snow falls is constantly in danger of heavy snow, which may prevent the completion of the harvest within the available time.

Where corn is husked mechanically, it will nearly always pay to go through the field after the picker to gather ears that may have fallen to the ground. In some instances animals on feed are permitted to roam the harvested field to gather the fallen grain.

Fodder Corn.—As a rule the operator who harvests fodder corn is one who is feeding livestock through the winter, and he may desire to

use the roughage available without the expense of the silo. This practice is not common in the heaviest producing areas where most of the grain is marketed but is more general in the more rolling sections where considerable land is in pasture and livestock is raised as a part of the farm enterprise. In southeastern and southern United States as well as many areas in the East it is common to harvest fodder corn.

Fodder corn should be harvested before it becomes too mature, or many of the leaves will be lost and the fodder will be less palatable and nutritious. Also, it should be cut just before a frost since the leaves fall quickly after the first freeze. Probably most farmers plan to harvest corn fodder at about the time the kernels are beginning to dent and it appears that the plant has attained its full development. Under normal conditions the plants will still be green at this time and, if harvested, most of the feeding value will be saved.

The general methods of harvesting fodder corn are cutting (1) by hand, (2) with a sled cutter, (3) with a corn binder. Where acreages are extensive the use of the corn binder is by far the most common method. If the plants are still green, they will contain much moisture, so that it is common to allow the bundles to lie on the ground for a day or two until they have lost some of the water. Then the bundles are placed in shocks by slanting them with the butt toward the outside and the tassels in, just enough to ensure a firm shock. Usually about 30 to 40 bundles of average size will be placed in one shock. Most farmers tie the shocks with twine about one-fourth of the distance from the top. A light rope with an iron ring is used to compress the shock so that the string may be tied tightly.

There is considerable loss in feeding value under the best of conditions, but to offset these losses there are the savings in labor and overhead as compared with the making of silage.

Where the winters are mild it is common to feed the fodder to livestock outdoors. Others place the fodder in large sloping racks so that the animals may feed with a minimum of waste. In some sections it is common to husk the ears from the bundles and to replace them in the shock for later feeding as stover. This is an expensive process but where practiced it is usually done in spare time when there is little demand for the available labor. Usually this method is most general on small acreages.

In the past it was common to haul shock fodder to a corn shredder which husked the corn and shredded the fodder. Generally this is not common, as it has been found to be a rather expensive method of har-

vest. In most corn-growing areas the shredder today is practically unknown.

Corn Silage.—In certain areas, particularly where dairying is important, the silo is considered by many farmers as an essential unit in farm enterprise. Most of the beef-producing farmers have discontinued the use of the silo, as they concluded that, based on the costs involved, silage was not a profitable feed.

One of the primary advantages of the silo lies in its provision of a large amount of succulent feed, which is highly important in helping to maintain the milk flow during the winter months.

FIG. 95.—The field harvester delivers the chopped corn into wagons or trucks, ready for elevating into the silo. (*Courtesy of G. H. Dugan, Illinois Agricultural Experiment Station.*)

Most farmers harvest corn for silage when the kernels of the ear are glazed and indentation has started. At this time the plants are green and carry most of their leaves. Wiggans[1] in detailed studies in New York found that neither extremely early nor late varieties were best for silage but rather that the best variety was one that utilized the major portion of the growing period to produce a yield of dry matter approaching the maximum for corn under a given set of environmental conditions.

Many farmers use a field cutter which cuts the corn in the field and delivers it in the wagon in a chopped form ready to be ensiled. The chopped corn is elevated to the silo through a blower pipe in much the

[1] WIGGANS, R. G., The Influence of Stage of Growth of Corn on Composition of Silage, *J. Am. Soc. Agron.*, **29**:456–467, 1937.

same way as with a regular silage cutter. This plan saves considerable labor as it is not necessary to handle the bundles twice. Also, the harvested product does not have the same opportunity to collect blade-dulling sand and other foreign materials.

A less complex arrangement permits the loading of the fodder directly from the binder to the wagon. With this plan the fodder is hauled to the cutter and ensiled in the conventional manner.

If the crop is frosted before maturity, the silo offers a splendid way of saving the crop, although the immature product will not necessarily be the best feed. In extremely immature corn, it is well to mix in a more mature crop from another field if such is available.

Types of Silos.—The principal type of silo is the aboveground type which is constructed of brick, hollow-tile, cement, steel, or wood.

In the pit silo the soil is removed with a scraper or other machine so as to form a pit. Such a silo is easy to fill but not so easy to feed from, since the silage must be lifted to remove it. At their best, such silos are not so desirable as the conventional types.

Many farmers have used the corncrib or slat-fence silo with success. These silos are inexpensive and make a fairly satisfactory substitute. Such silos should be at least 16 ft. in diameter and at least 20 ft. high and should be lined with waterproof building paper to reduce the hazards of spoilage.[1] Corncrib silage should be well packed to prevent air pockets.

Stack silage may be made by piling green-corn bundles in a stack at least 18 to 20 ft. in diameter and several feet in height, as it is necessary to get considerable height to ensure good settling. The bundles are piled with the butts toward the outside with the center kept low. Such silage will spoil on the outer edge for 8 to 12 in., and this damaged material should be discarded since it may be injurious to livestock.

Size of the Silo.—Generally the size of the silo is directly related to the size of the farm, the number of animals that are to be fed during a season, and the amount that is to be fed to each animal daily. If each cow is fed 40 lb. of silage per day, it is simple to compute the amount of feed required for 20 cows to be fed over a period such as 6 months. From these calculations one can determine the size of silo needed. Table 43 gives the capacity of round silos and the amount that should be fed daily to remove 2 in. of silage and make certain that all is fed before spoilage occurs.

[1] ANONYMOUS, The Corn Crib or Slat-fence Silo, *Minn. Agr. Extension Folder* 49, 1934.

TABLE 43.—CAPACITY OF ROUND SILOS AND AMOUNT FED DAILY TO REMOVE 2 IN. OF SILAGE

Inside diameter, ft.	Height, ft.	Capacity, tons	Amount removed, lb.
10	25	31.8	525
10	35	50.7	525
12	30	58	755
12	40	88	755
12	50	120	755
14	30	80	1030
14	40	120	1030
14	50	164	1030
16	35	129	1340
16	45	184	1340
18	35	164	1700
18	45	234	1700
18	50	271	1700

Although the figures in the table are not exact, varying somewhat with the stage of development and the quality of the corn, they do serve in determining the size of silo required. If a silo is to be constructed, it is well to make it large enough for all future needs since the added cost for increased capacity is relatively small in relation to the whole.

Frequently, farmers wish to know how much silage remains in a silo after a part has been fed. Usually this question arises when a tenant leaves silage or a new owner takes over and agrees to purchase the silage. For these computations the schedule in Table 44 will prove of real value in arriving at a rather accurate determination.

TABLE 44.—WEIGHT PER CUBIC FOOT OF SILAGE REMAINING IN SILO

Feet Down	Pounds per Cubic Foot
1	18.8
3	31.4
5	38.2
10	46.5
15	50.4
20	53.0
25	55.0
30	56.2
35	57.8

The figures in the table are from results obtained in one of six silos studied by Shepherd and Woodward[1] at Beltsville, Md.

As would be expected, the farther down the silage, the more it will be packed and the greater the weight of a cubic foot. To utilize the data in Table 44 one must determine the total cubic feet remaining in the silo. If a silo 12 by 40 ft. contained 35 ft. of well-settled silage and

FIG. 96.—Twin silos, Brook Hill Farm, Genesee Depot, Wisconsin. (*Courtesy of Harold Hedges, U.S. Department of Agriculture.*)

the tenant had fed off 15 ft., to determine the amount remaining, he would use the formula r^2 (radius) $\times \pi$ (3.1416) $\times$ the depth of silage remaining. This would give the cubic feet of silage, which multiplied by the weight of a cubic foot of silage at that depth would give the weight in pounds. To carry the problem through, $6 \times 6 \times 3.1416 = 113.1$ sq. ft. $\times 35 = 3{,}958.5$ cu. ft. $3{,}958.5 \times 56.8$ lb. (weight of cubic foot of silage at 35 ft.) = 224,842.8 lb. in silo after settling.

[1] SHEPHERD, J. B., and T. E. WOODWARD, Estimating the Quantity of Settled Corn in a Silo, *U.S. Dept. Agr. Circ.* 603, 1941.

The amount fed out was 15 ft. $15 \times 113.1 = 1{,}696.5$ cu. ft. $\times 50.4 = 85{,}503.6$ lb. fed out. $224{,}842.8 - 85{,}503.6 = 139{,}339.2$ lb., or 69.7 tons, remaining in the silo.

Soybeans with Corn for Silage.—Some farmers grow soybeans and corn as a combined crop for silage. This practice has the advantage of giving a silage that is richer in protein and a better-balanced feed. The practice is not general, however, as there is some added inconvenience in handling the two crops. Wiggans[1] states that the shading of the beans by the corn decreases the total dry-weight production. He found that the percentage total dry matter of the corn was not significantly changed but that the percentage of dry shelled grain in the total dry matter was significantly reduced.

In earlier work, Slate and Brown[2] reported an advantage of soybeans and corn for silage over the growing of the crops alone. They advised drilling the two crops with one hill of corn to three of beans for each 12 in. of row.

Hogging Off.—The term *hogging off* or *sheeping down*, depending upon which class of animals is used, is a common term among corn farmers. As the name implies, it is a method of harvesting in which the animals are given access to the field and in reality harvest the crop as they consume it.

The principal advantages of hogging off are the saving in labor and storage costs of the harvested grain. About the only labor involved is the placing of temporary fencing so as to confine the animals to a relatively small area. This is highly desirable to avoid the undue waste that results if the stock is permitted to cover too large an area. A roll of woven wire and a few stakes or steel fence posts make it easy to fence off parts of the field at little cost. As soon as the animals have cleaned up the corn in a given section, the fence is moved and more corn is made available.

It is desirable to place the hogs on full feed before they are turned into a field, or digestive disturbances may occur. It is profitable also to provide shade and water in the field and a self-feeder with a protein supplement such as tankage.

Disadvantages of hogging off are that when the season is wet and the soil becomes muddy much of the grain is wasted. Even under

[1] Wiggans, R. G., The Effect of Growing Corn and Soybeans in Combination on the Percentage of Dry Matter in the Two Crops, *J. Am. Soc. Agron.*, **26**:59–65, 1934.

[2] Slate, W. L., Jr., and B. A. Brown, Corn and Soybeans as a Combination Crop for Silage, *Storrs Conn. Agr. Expt. Sta. Bull.* 133, 1925.

favorable conditions there is some waste, but this is largely offset by the saving of labor.

The use of sheep to utilize the corn crop is not so common. Many farmers turn lambs into the standing corn to clean up weeds and to utilize the lower leaves of the corn plant. There is some danger of sickness when the sheep are permitted to eat the corn, and care must be taken to accustom them to the full feed and to watch for sickness which may develop.

Cattle, and in some cases horses, have been used to harvest standing corn, but the practice is not general.

STORAGE OF EAR CORN

Much of the corn crop is stored for varying lengths of time following husking. As it is too moist to shell for market, it is necessary to store it until drying has occurred. With the coming of cold weather, under proper crib conditions, the moisture content is reduced and the corn may be shelled and marketed. If the corn is to be fed on the farm, then it is utilized as needed regardless of its moisture content, exercising the usual care in feeding green and not fully dried corn to livestock.

The storage of corn that is being produced for seed is very different in the main from that of a bulk commercial crop. In the storage of seed corn it is necessary that the grain be dried to a point where the viability will not be affected by low temperatures. This means that seed corn must be harvested before cold weather, and the problems of drying are intensified by the greater moisture content of such grain.

Corn that is not thoroughly dry may be shelled during the winter months and marketed while the water content is high. Such corn receives a considerably lower price, as the purchaser must dry it before it can be stored. Such wet corn must be utilized before the coming of warm weather, or spoilage is certain to occur. The farmer who finds himself with corn of a high water content will find it more profitable under most circumstances to feed the grain to livestock.

Types of Cribs.—Most ear corn is stored in structures commonly known as *corn cribs*. In general, the following types of cribs are used: (1) the slatted-wood crib, (2) cement stave, (3) hollow tile, (4) steel, and (5) temporary cribs of snow fencing, wire, or similar materials.

The use of wooden slatted siding makes a very desirable type of corn crib. In general such a crib should not be more than 8 ft. wide, as greater widths result in poorer ventilation. Many of these structures are constructed as double cribs with a driveway in the center. The driveway may be used as a machine shed during most of the year. The

siding is spaced as far apart as possible to permit free access of air, and it is well to provide for cross-ventilation if the corn is not thoroughly dry. Temporary boxlike frames may be used at intervals to permit the circulation of air.

The principal disadvantage of the wooden crib is that it affords no protection from rats and mice, which normally do much damage to the stored grain.

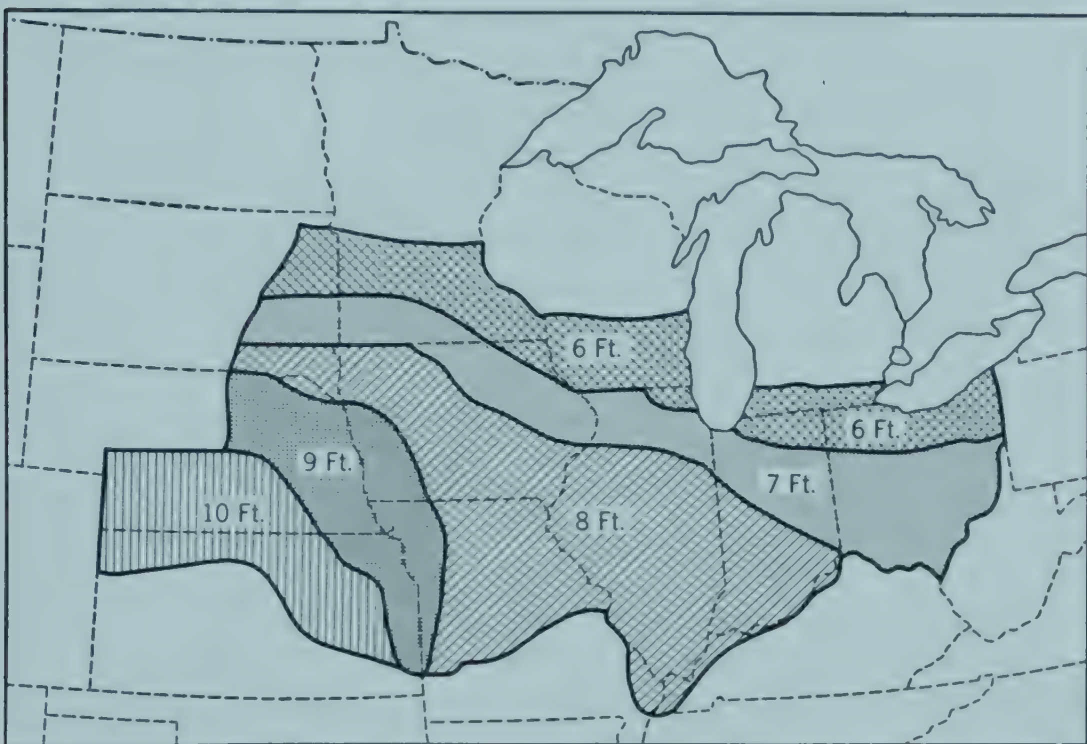


Fig. 97.—Maximum crib widths recommended for the commercial corn area. (*Courtesy of C. K. Shedd, Bureau of Plant Industry, U.S. Department of Agriculture.*)

Cement-stave cribs are somewhat expensive but do provide against rat damage and are much more permanent.

Hollow-tile cribs are more common than the cement-stave type. They usually are less expensive than the concrete crib and have all its advantages.

The steel crib is not so well suited for ear corn that is high in moisture, since ventilation is difficult and some artificial means of aeration must be provided. Steel cribs are used more generally for shelled corn after it has been dried to a stage that will permit safe storage.

Temporary cribs are very common, especially in areas where corn is a major crop and few if any animals are fed on the farm. At their best these cribs provide rather inadequate protection. Many of them

are constructed of rolls of slatted snow fencing which is braced to prevent collapse. Over the top it is advisable to place boards, metal roofing, or cornstalks, although in many cases no covering is given. Woven wire may be used for cribbing but it is more flexible and consequently more difficult to brace properly than the snow-fence type. These cribs are ideal harbors for rodents, and if the corn is left for any period of time much loss results. Many of the farmers who use these cribs plan to shell the corn during the winter months and market it before the coming of spring rains and warmer weather.

Drying Hybrid Seed Corn.—Many types of cribs have been developed for the drying of hybrid seed corn. The essential requirements of a good drier are to provide a furnace that can furnish a temperature of 100 to 110°F. throughout the bin; a fan that will blast the air through 5 to 7 ft. or more of solidly packed corn, and false or slatted bottoms under the corn to permit the entrance of the heated air. Various models are available commercially, or an ingenious individual may construct his own drier.

The corn should be dried until the moisture is reduced to 12 to 14 per cent. Such corn is safe from injury from extreme cold and may be stored without danger of heating. After being dried the ears may be shelled and the corn stored in steel or other types of tight bins.

SOFT CORN

It is not uncommon in the northern part of the corn belt to have a frost before corn is thoroughly matured, resulting in what the farmer refers to as *soft corn*. A prospective bumper crop of corn may become nearly worthless as the result of an early frost. The problem is not confined to the Northern states but may arise wherever corn is grown. The hazard is sufficiently great so that every corn farmer should consider in advance what he will do if he is confronted with a crop of immature corn.

The Causes of Soft Corn.—Soft corn may be the result of growing unadapted varieties that require a longer growing season than is available. Many farmers attempt to grow larger and later maturing varieties than are adapted. The coming of hybrid corn with closer regulation of the sale of seed corn has aided greatly in reducing these risks. In many states the state laws require the seller to indicate to the farmer the average number of days required to grow the variety. The result of this has been to make growers more cognizant of seasonal requirements and hazards, leading to a more careful choice of variety.

In wet, cool seasons the maturity of corn is often delayed, and even

adapted varieties may fail to mature properly. In some seasons the farmer can foresee the probability of soft corn and can plan to preserve it by special methods or to utilize it as feed. A rainy September may lead to trouble, as the corn is held in check.

In some years frosts are unusually early and catch the corn crop. These are not predictable and may occur in any year. Of course the early frost is generally a greater hazard in the more northern sections and usually finds the farmer unprepared.

Utilizing Soft Corn.—How can a farmer meet the soft-corn problem so as to reduce the losses that result? Several possibilities are available, depending upon a number of factors. These may be summarized as follows:

1. *Use as Silage.*—The farmer who has a silo can make good use of his soft corn, regardless of its stage of immaturity. The principal difficulty lies in the fact that this cares for but a part of the crop on most farms. Some farmers have filled the silo twice during the year, filling once immediately after frost, while the other corn is cut and shocked. When the silo is emptied during the winter, it is refilled with the shock fodder. This involves the addition of considerable water, about 1 lb. of water for each pound of fodder, to ensure proper silage. In a few cases farmers have snapped the ears and filled the silo with these. This will save a large quantity of corn but results in the loss of most of the stalks which with immature corn are of much greater feeding value.

2. *Cribbing the Soft Corn.*—This is a practice followed by farmers wherever possible. If only a part of the crop is soft, it may be sorted if husked by hand, but this is impractical when a mechanical husker is used. Usually husking is delayed as late as possible and the corn is placed in cribs equipped with ventilating devices to ensure the free movement of air. The addition of about 1 lb. of salt to each 100 bu. of corn helps to reduce the development of molds on soft corn. The salt is scattered over the corn in layers so that as many of the ears may be reached as possible. Where livestock is available it is advisable to feed this corn as rapidly as possible so that it may be utilized before the coming of warm, moist weather in the spring. It is at this time that the danger from spoilage is greatest, especially if the crib is of such type that it provides inadequate protection and poor ventilation. Many farmers who anticipate a soft-corn crop purchase extra feeder pigs or cattle and definitely plan to dispose of the crop in this way.

3. *Artificial Drying.*—For the most part this is not practical on the average farm since it requires the installation of expensive equipment. The producer of hybrid seed corn who is equipped with drying facilities

may use them to good advantage to dry commercial corn, but most farmers will not be able to resort to artificial drying methods.

4. *Fodder Corn.*—Much soft corn may be used to advantage on the livestock farm by cutting it for fodder. The stalks are very nutritious and may be utilized in this manner. Bundles should be smaller and placed in relatively small shocks to facilitate drying without spoilage.

5. *Marketing Soft Corn.*—It is difficult to sell soft corn in most years as there is so much available. When the weather is cold so that it may be shelled and hauled to market, usually the elevators will purchase such corn but are limited as to the amount that can be dried artificially, since the corn when it reaches the terminal markets is passed through corn driers. Naturally the price is much lower, and it will pay the grower to utilize the crop on the farm if at all possible.

Shedd[1] has made special studies of the storage of soft corn. He states that in central Iowa corn should be mature by about Sept. 15 to 20 in order that it may not be necessary to resort to artificial drying. If corn containing more than 20 per cent moisture is cribbed without provisions for aiding drying, some spoilage may be expected.

To determine the safety of storage at least 20 ears should be gathered at random, as representative of the general condition of the field. Two rows of kernels are removed from each ear, using a screw driver to shell the grain. The shelled grain should be sealed at once in a fruit jar and taken to the local elevator for a moisture test. The taking of several samples adds to the reliability of the test.

Shedd gives the following directions for the harvesting of corn with different moisture percentage:

Corn with 20 to 25 Per Cent Moisture.—Delay harvest until cool weather. Husk very clean. Remove all shelled corn as it goes into the crib. Sort out soft or immature ears. Use crib ventilators, and avoid wide cribs.

Corn with 25 to 30 Per Cent Moisture.—The corn should not be harvested until the weather is cold. Observe the precautions listed above, and remove all soft ears, shelled corn, and husks. Use a narrow crib and provide ventilators. The corn must be watched carefully with the coming of warm weather in the spring. If the corn begins to heat, the ears should be removed and all soft ears sorted out. An elevator aids greatly in making this job less burdensome. The mere moving of the corn will aid greatly in the speeding of the drying process.

[1] Shedd, C. K., Storing Soft Corn in Cribs, *U.S. Dept. Agr. Research Admin. Mimeo. Leaflet.*

Corn Containing More Than 30 *Per Cent Moisture.*—It is impractical to keep this corn after the end of cold weather. If it is shelled and marketed during cold weather, it may be salvaged at a greatly reduced price. However, to keep it beyond cold weather it must be artificially dried or moved often and placed in small lots to prevent heating and spoilage.

Shedd has devised six types of ventilators, as illustrated on pages 306 and 307. These are removable devices that are designed to facilitate the movement of air and the loss of moisture.

Ventilator *A* should be placed through the center of the crib from end to end with half of the end-wall siding boards removed to permit the free passage of air. Corn should not be placed above the top of the ventilator until late in the season. The ventilators may be made in sections which are easily handled.

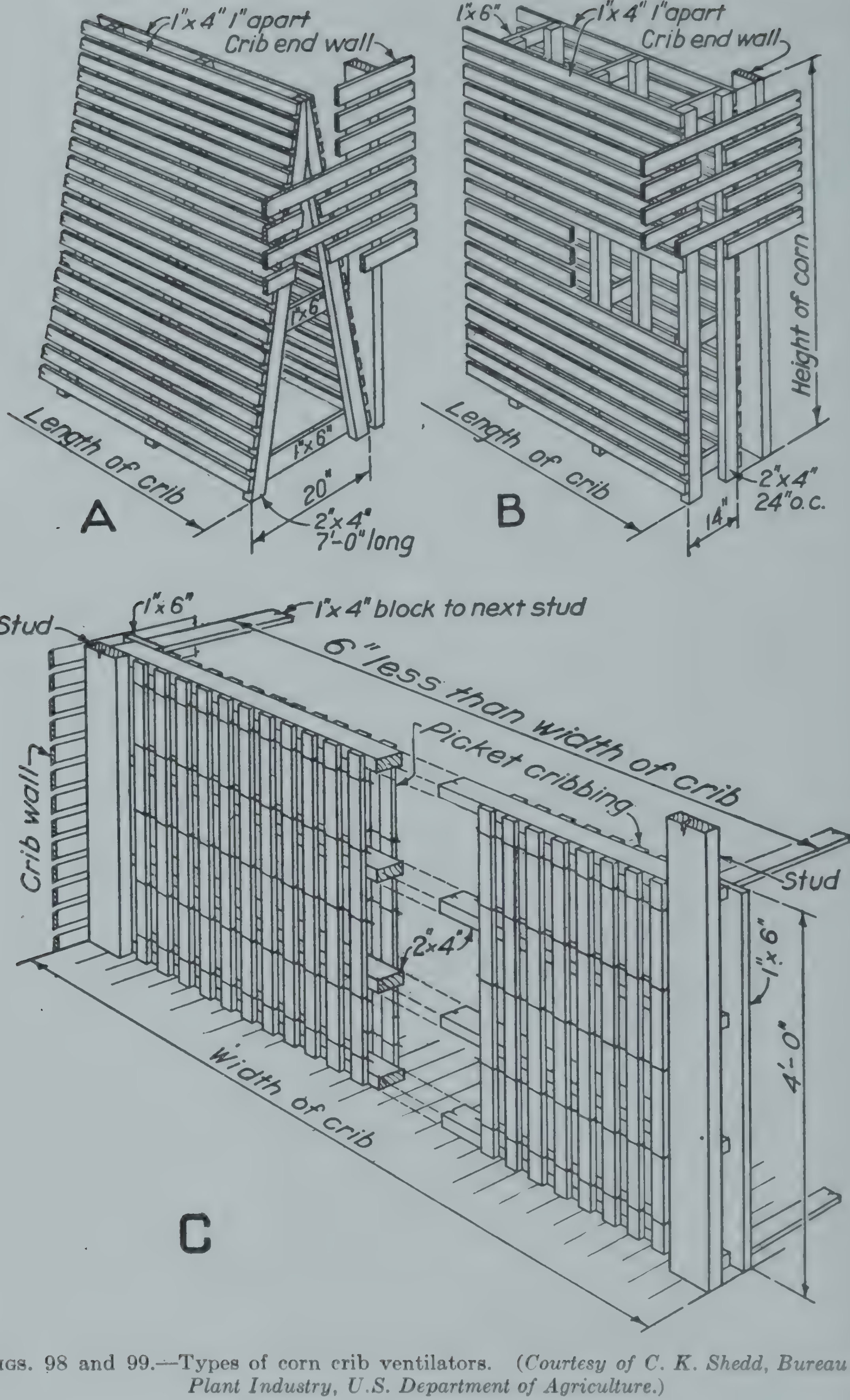
Ventilator *B* is the most effective type if it can be used. This type is placed through the center of the crib to the full height of the corn. One-half of the siding boards are removed at the end walls to permit air passage through the ventilators. The principal objections are (1) the large amount of lumber required; (2) the cross ties interfere with installation; (3) when built in sections between cross ties, these are difficult to move; and (4) it is unhandy to empty the crib as both sides must be opened.

Ventilator *C* is cheap and light in weight since it is made of picket cribbing. It is made in sections about 4 ft. high, and the sections are placed one upon the other to the top of the corn. This ventilator is placed crosswise from wall to wall. This type of installation is less inconvenient in the removal of the corn since it is placed at right angles to the length of the crib.

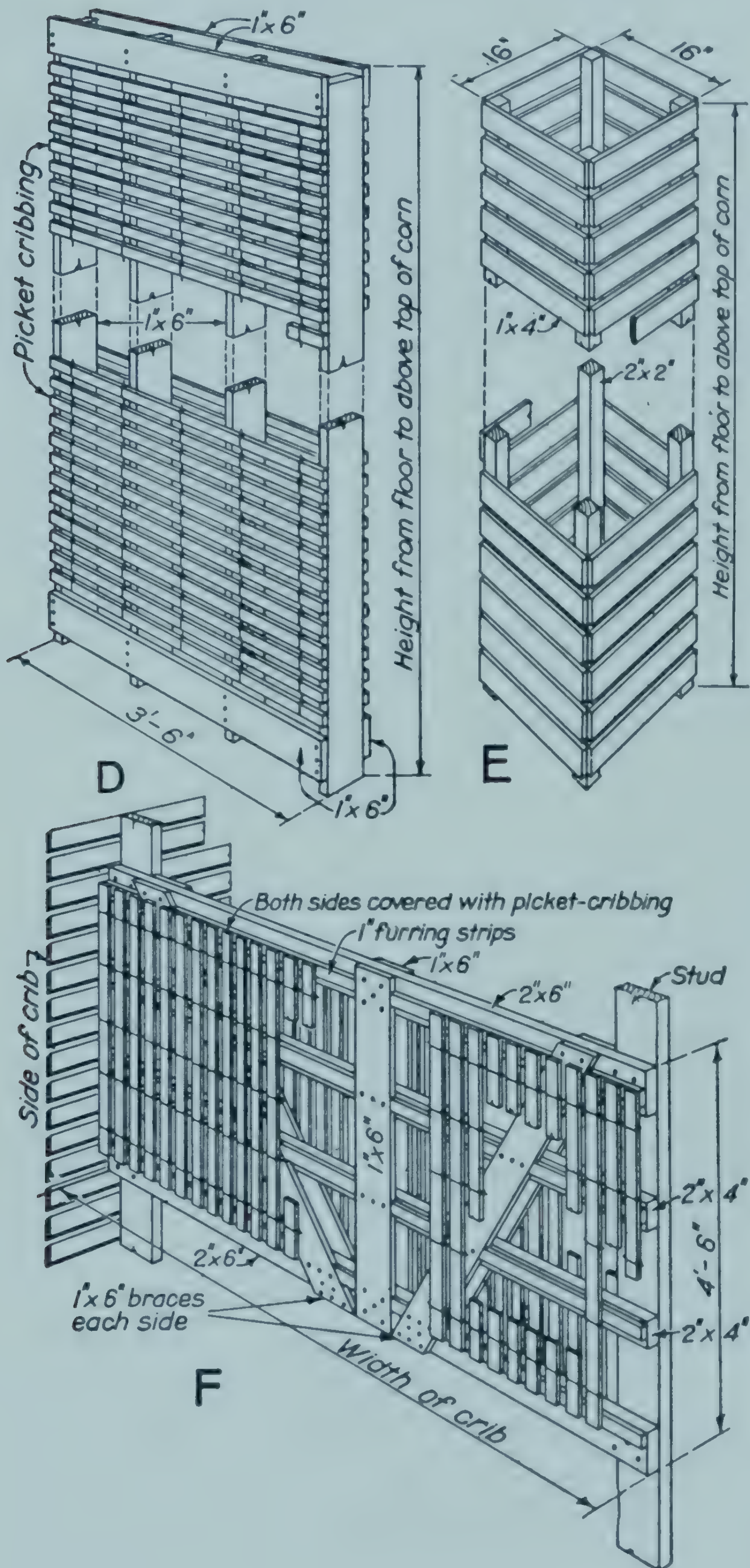
Ventilator *D* is also cheap and light as it is made of picket cribbing. It may be placed either crosswise or lengthwise of the crib. As air movement is up and down, the ventilator must be open at the top to permit the free passage of air.

Ventilator *E* is used much the same as ventilator *D*. It is constructed from 1 by 4 in. lumber and so is more expensive than the picket-cribbing types.

Ventilator *F* provides both ventilation and bracing. The ventilator height of 4 ft. illustrated is designed for a crib 12 ft. high. This is a permanent device and should be placed at least 6 ft. 6 in. above the level of the floor to permit ample head room at the time the corn is removed. The permanent ventilators are spaced 4 ft. apart. If the stored corn



FIGS. 98 and 99.—Types of corn crib ventilators. (*Courtesy of C. K. Shedd, Bureau of Plant Industry, U.S. Department of Agriculture.*)


1"x 6"
Picket cribbing
1"x 6"
Height from floor to above top of corn
3'-6"
1"x 6"
D
16"
16"
1"x 4"
2"x 2"
Height from floor to above top of corn
E
Both sides covered with picket-cribbing
1" furring strips
1"x 6"
2"x 6"
Stud
Side of crib
1"x 6"
2"x 4"
4'-6"
2"x 4"
2"x 6"
1"x 6" braces
each side
Width of crib
F

contains more than 25 per cent moisture, it will be necessary to use removable ventilators beneath the permanent ventilator.

Shedd has listed several methods of reducing the problems of soft corn.

1. Delay harvest as long as possible.
2. Harvest the parts of the field on higher ground first.
3. Do not harvest when the husks and silks are wet from frost, snow, or rain.
4. Equip the picker with a fan to remove loose materials.
5. Sort out soft corn.
6. Screen out soft corn.
7. Move the elevator spout often to reduce the concentration of shelled corn in one spot.
8. Place corn in shallow layers during the first part of the season.

Review Questions

1. How is corn harvested in your community?
2. What are the advantages of hogging off corn?
3. What disadvantages can you see to the practice of hogging corn?
4. List the advantages of the mechanical husker.
5. Under what conditions would you advise the use of fodder corn?
6. Why has the shredder tended to disappear?
7. Under what conditions would you recommend the use of the silo?
8. What are the advantages of silage as a feed?
9. Why is it important that silage be fed out at regular intervals?
10. How is silage preserved?
11. Would you recommend the growing of soybeans with corn? Why?
12. What type of crib would you use for the storage of ear corn?
13. What are the disadvantages of temporary cribs?
14. At what moisture percentage is it safe to crib corn?
15. How can you save soft corn?
16. Devise a plan for aerating your home crib. Give details of construction.
17. What effect does salt have on soft corn?
18. Why is it advisable to build narrow cribs?
19. How can the farmer reduce the losses from soft corn?
20. How is variety of corn grown related to the problems of soft corn?

References

Bohstedt, G., E. J. Delwiche, N. P. Neal, W. H. Peterson, P. H. Phillips, and S. P. Witzel: Good Corn Silage, *Wis. Agr. Ext. Circ.* 537, 1943.

Hughes, H. D., and E. R. Henson: "Crop Production," The Macmillan Company, New York, 1930.

Myers, K. H.: Methods and Costs of Filling Silos in the North Central States, *U.S. Dept. Agr. Farmers' Bull.* 1725, 1934.

Nevens, W. B., and G. H. Dungan: Yields of Corn Hybrids Harvested for Silage. *Ill. Agr. Expt. Sta. Bull.* 494, 1942.

Price, F. E., and Ivan Branton: Corn Drying, *Ore. Agr. Expt. Sta. Bull.* 352, 1937.
Shedd, C. K., and E. V. Collins: Mechanizing the Corn Harvest, *U.S. Dept. Agr. Farmers' Bull.* 1816, 1938.
———: Machinery for Growing Corn, *U.S. Dept. Agr. Circ.* 592, 1940.
———: Handling and Storing Soft Corn on the Farm, *U.S. Dept. Agr. Farmers' Bull.* 1976, 1945.
Wallace, H. A., and E. N. Bressman: "Corn and Corn Growing," 4th ed. revised, John Wiley & Sons, Inc., New York, 1937.

CHAPTER XIX

SWEET CORN

Sweet corn is typically an American food, being utilized no where in the world as widely as in its birthplace, the Western Hemisphere. Nearly every man, woman, and child in America relishes sweet corn, not only as a fresh garden delicacy but also as a staple article of canned food. The canning industry is one of the most important in the United States. During the 10 years 1933–1942, the farmers of this country produced an average crop of 886,300 tons of sweet corn each year for which they were paid more than $10 million annually. Where sweet corn canneries are located, the crop is of great importance and ranks high in cash value and returns. Generally speaking, the crop is not grown extensively for canning. Production is highly specialized, and only a limited acreage is required to meet market demands. For the most part, canning factories have been located in suitable areas where the canning companies contract with the growers for the acreage desired to operate their plants. In many places other types of products such as peas are processed, since this helps to distribute the required labor over a longer season.

BOTANY OF SWEET CORN

Tapley, Enzie, and Van Eseltine[1] doubt the desirability of classifying sweet corn as *Zea mays saccharata.* They state that varieties classified in one group can also be placed in one or more of the other groups. Weatherwax[2] summarizes the work of East and others as follows:

> Sweet corn is apparently the same as other varieties except that it has lost its ability to produce fully developed starch grains. Hybridization of sweet varieties with soft starchy varieties produces grains indicating that sweet corn may be differentiated into soft, flinty, and dent varieties that cannot synthesize starch efficiently.

East[3] believed that sweet corn varieties were dent, flint, or popcorn types that had lost their ability to make starch.

[1] Tapley, W. T., W. D. Enzie, and G. P. Van Eseltine, The Vegetables of New York, Vol. 1, Part III, Sweet Corn Report, *N. Y. Agr. Expt. Sta.*, 1934.

[2] Weatherwax, Paul, "The Story of the Maize Plant," University of Chicago Press, Chicago, 1923. Reproduced by permission.

[3] East, E. M., A Note Concerning Inheritance in Sweet Corn, *Science*, **29**:465–467, 1909.

AGRONOMIC TYPES OF SWEET CORN

Sweet corn varieties may be classed in two general groups: (1) the old open-pollinated varieties, many of which have been grown for years; and (2) the hybrid varieties which have been bred to produce higher yields of a superior-quality product.

Most sweet corn varieties have kernels that are either white or yellow, although a few black-kerneled varieties are grown. A very complete listing of the older varieties has been prepared by Tapley *et al.*, in the publication referred to above. Here the varieties have been classified primarily on the basis of kernel color.

The development of the Golden Bantam types of corn led to increased interest in yellow-seeded varieties. Today, the tendency is toward the yellow varieties, and many of the breeding programs are so directed. The modern varieties are subjected to various tests for palatability, toughness of pericarp, and general all-around suitability for canning purposes. Many of these are so far superior to the old varieties that many producers no longer grow the old types, and some canning companies pack only corn that is produced from hybrid varieties.

Hybrid sweet corn did not assume any importance until the introduction of Golden Cross Bantam in 1932, a variety produced by the Indiana Agricultural Experiment Station and the United States Department of Agriculture.

Singleton[1] states that the first commercial sweet corn hybrid in Connecticut was developed by Dr. D. F. Jones of the Agricultural Experiment Station. This variety, known as Redgreen, was introduced in 1924. Since that time the Connecticut station has produced many improved varieties. Several of the agricultural experiment stations are engaged in sweet corn breeding activities, and most of the large sweet corn canning companies maintain research staffs devoting a part of their time to a breeding program. More will be said concerning this and related problems in the discussion of corn improvement.

No list of varieties can be kept up to date, and it is important that the student become familiar with the latest recommendations of his state agricultural experiment station.

WHERE SWEET CORN IS GROWN

As a commercial crop, market gardeners in the vicinity of nearly every city produce some sweet corn for the grocery trade, but as a

[1] SINGLETON, W. RALPH, Sweet Corn Breeding in Connecticut, article in Sweet Corn for Canning, National Canners' Association, Bureau of Raw Products Research, Washington, D. C., 1941.

canning crop, sweet corn is important in relatively few states. The leading states in order of total production for the period 1933–1942 are given in Table 45.

In each of the states where sweet corn is an important crop, commercial canning factories operate to process the crop. Under these conditions sweet corn is grown on a large scale much the same as other field crops.

TABLE 45.—AVERAGE TOTAL PRODUCTION OF SWEET CORN OF LEADING STATES FOR THE YEARS 1933–1942

State	Tons in husk	Average price per ton
Minnesota	158,700	$8.00
Illinois	149,000	9.50
Iowa	78,000	7.50
Indiana	71,900	10.00
Maryland	69,800	11.00
Wisconsin	61,600	9.00
New York	45,700	11.50
Ohio	44,000	8.60
Maine	43,700	16.00
United States total	886,300	$9.79

As is evident from the list of important states, the crop is grown largely in the Northern states. Here are found favorable environmental conditions for sweet corn. It is not an important canning crop in the South, mainly because of a greater insect problem, particularly the corn earworm, which greatly reduces the percentage of marketable ears. Also sweet corn produced in a cool climate tends to be much more tender than that produced where the summer temperatures are high.

Generally, sweet corn for the cannery is a profitable crop. In the nine leading states, as listed in Table 45, the average annual production for the 10-year period was a little over 2.1 tons per acre, and the average price was $10.10 per ton. On the basis of the average price, the average return to the farmer was $21.21 per acre. The returns varied with the states, being lowest in Iowa with an average return of $16.54 per acre and highest in Maine with an approximate value of $60.31 per acre. The differences here are due largely to greater yields and a higher price in Maine than in Iowa.

CULTURE OF SWEET CORN

In general, the culture of sweet corn is much the same as that of field or dent corn, but there are certain factors that should be considered by the farmer who plans to grow the crop. Naturally, before the crop is grown it is desirable to make certain of a market. Where one lives in the vicinity of a canning factory, the market problem is solved. It is common in these areas for the canning company to contract with the

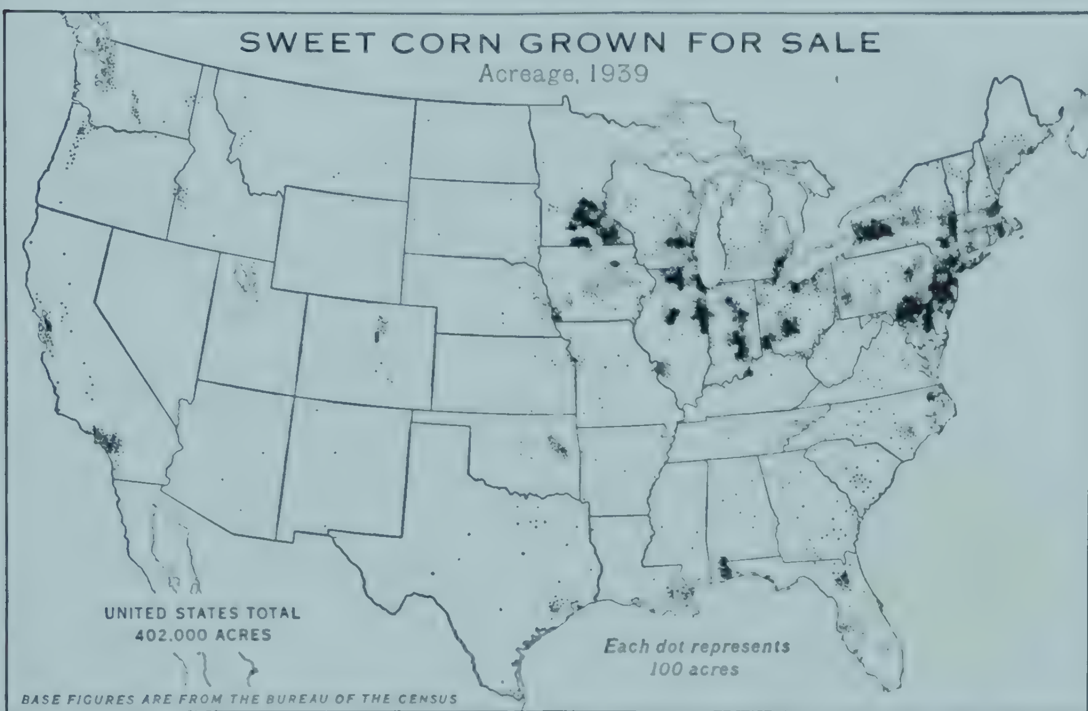


FIG. 100.—Acreage of sweet corn in the United States. (*Courtesy of the U.S. Department of Agriculture.*)

farmer to produce the crop. In most cases the company will choose the variety and advise the grower as to fertilization, methods of culture, and harvest.

Soil.—Any good corn land is suitable for sweet corn production, a heavy loam being especially suited. Sandy loams that are fertile are excellent since they warm somewhat earlier and produce a crop for the early market, a factor of especial importance to the market gardener. Most growers use barnyard manures and commercial fertilizers, particularly nitrogen- and phosphorus-bearing types, to ensure heavy production.

Seeding.—Usually sweet corn germination is more susceptible to injury from cool spring weather than is field corn. For this reason, on a field scale it is planted slightly later, making certain that the soil is warm. The corn may be drilled or checked as is common with field

corn. In recent years, many growers are finding that it pays to plant at heavier rates by spacing the rows more closely. Since the crop is harvested before maturity, there is less danger of drought injury in late summer than is the case with field corn. The canning company usually arranges for a variation in planting dates in a community to provide for a greater spread of the canning season.

Cultivation.—The practices are the same as for field corn, with enough tillage to control the weeds.

FIG. 101.—Sweet corn is managed in much the same manner as field corn. (*Courtesy of the J. I. Case Company.*)

Harvesting.—Sweet corn is harvested when the kernels are at the proper stage to eat as green corn. This is checked carefully by the representatives of the canning company to ensure the highest quality. Too early harvest results in a soft low-quality product, while delayed harvest means more toughness and decreased sugar content of the corn. Since but one harvest is made, it is necessary to choose a time when the greatest percentage of the corn is prime. A great advantage of the hybrid varieties lies in the greater uniformity of maturity and consequently less waste from variable maturity. The common method of harvesting is to drive a rack-equipped wagon through the fields, snapping all ears by hand. The snapped corn is hauled to the cannery, where it is processed as rapidly as possible.

Since sweet corn is harvested before maturity, it does not take as much fertility from the soil as field corn which grows to maturity. The stalks provide valuable feed and may be ensiled or cut and shocked for later feeding as fodder corn.

The canning factories usually pile the husks and other refuse into a stack and make stack silage which is of fair quality. Since it lacks the ears, it is not so palatable or valuable as silage made from mature corn with the ears attached.

Review Questions

1. How does sweet corn differ from field corn?
2. What states lead in sweet corn production?
3. Why do certain states produce much more sweet corn than others?
4. What advantages does hybrid sweet corn have over the open-pollinated varieties?
5. Why is it desirable to can sweet corn immediately after harvest?
6. List the principal insects attacking sweet corn.
7. How may the insects be controlled?
8. How does sweet corn rank as a cash crop?
9. How does the culture of sweet corn differ from that of field corn?
10. How is sweet corn harvested?
11. What use is made of the husks?
12. What fertilizers may be used to advantage to further sweet corn production?
13. What varieties of sweet corn are grown in your community?
14. How do the problems of the market gardener producing sweet corn differ from those of the farmer raising corn for canning?
15. Why is sweet corn normally planted a little later than field corn?

References

Barrons, K. C.: Marketing Husked Sweet Corn, *Mich. Agr. Expt. Sta. Quart. Bull.* Vol. 23, No. 4, 1941.

Beattie, J. H.: Growing Sweet Corn for the Cannery, *U.S. Dept. Agr. Farmers' Bull.* 1634, revised 1945.

Clinton, G. P., and W. R. Singleton: Stewart's Bacterial Wilt on Sweet Corn, *Conn. Agr. Expt. Sta. Circ.* 96, 1934.

Enzie, W. D.: Yellow Sweet Corn Hybrids for New York, *N. Y. (Geneva) Agr. Expt. Sta. Bull.* 686, 1939.

———: The Relation of Spacing to Yield and to Plant and Ear Development of Some Yellow Sweet Corn Hybrids in New York, *N. Y. (Geneva) Agr. Expt. Sta. Bull.* 700, 1942.

———: A Descriptive and Historical Study of Some Yellow Sweet Corn Hybrids, *N. Y. (Geneva) Agr. Expt. Sta. Bull.* 705, 1942.

Haber, E. S.: A Study of Drouth Resistance in Inbred Strains of Sweet Corn *Zea mays* var. *rugosa*, *Iowa Agr. Expt. Sta. Research Bull.* 243, 1938.

Huelsen, W. A., and W. H. Michaels: The Yield Complex of Sweet Corn, *Ill. Agr. Expt. Sta. Bull.* 432, 1937.

———: Sweet Corn Inbreds and Crosses, *Ill. Agr. Expt. Sta. Bull.* 466, 1940.

———: Yield of Sweet Corn in Relation to Distance and Rate of Planting, *Ill. Agr. Expt. Sta. Bull.* 487, 1942.

HUGHES, H. D., and E. R. HENSON: "Crop Production," The Macmillan Company, New York, 1930.

PRINCE, F. S., and P. T. BLOOD: Fertilizers for Sweet Corn, *N. H. Agr. Expt. Sta. Circ*, 63, 1943.

SINGLETON, W. R.: Sweet Corn Trials at Mt. Carmel, Connecticut, *Conn. Agr. Expt. Sta. Rept. of Progress*, 44G2, 1944.

Sweet Corn for Canning, National Canners' Association, Washington, D. C., 1941.

WALLACE, H. A., and E. N. BRESSMAN: "Corn and Corn Growing," 4th ed. revised, John Wiley & Sons, Inc., New York, 1937.

CHAPTER XX

POPCORN

There are few people who do not relish freshly popped corn liberally sprinkled with rich butter and salt. Most Europeans and peoples in other parts of the world have never learned to appreciate the value of popcorn as a food, and it appears that in all probability it will continue to remain primarily an American crop. For the most part, popcorn is grown in small fields for local consumption, with only a few states entering into commercial production.

BOTANY OF POPCORN

Popcorn was classed by earlier workers as *Zea mays everta*, although later workers have tended to drop the subspecies rank. It is known that other types of corn may pop under certain conditions. The flints in particular will pop if the moisture content of the grain is correct, although the quality of the product is not nearly so desirable as that obtained from the true popcorn varieties.

According to Brunson and Bower[1], the popping process is the result of the sudden release of the pressure produced by steam generated within the kernel when it is heated. The colloidal matrix holding the starch grains together confines the steam until the pressure becomes so great that it literally explodes with the release of the pressure. This ability to pop is based upon the toughness and elasticity of the hard starch which effectively prevents the rupture of the grain until fairly great pressure has been built up within the seed. The seed of well-matured popcorn contains very little soft starch, most of which surrounds the germ. The arrangement of the starches in dent corns rather effectively prevents their popping properly, and usually when heated the kernel merely cracks open with very little or no expansion.

Popcorn expands best when popped if the grains contain about 13 per cent moisture. If corn is stored in a dry heated room, it will become too dry to pop properly. The condition may be corrected by adding water and then storing in tight containers for 24 to 48 hr. to permit absorption of the water. A good plan is to store the popcorn under the

[1] Brunson, A. M., and C. W. Bower, Popcorn, *U.S. Dept. Agr. Farmers' Bull.* 1679, 1931.

roof of a porch or other place where it comes in contact with outside air but is not exposed to rain or snow. After corn is at the proper stage to pop well, it may be stored in tight fruit jars until used.

Temperatures for popping should be neither too hot nor too cold. A little practice will enable one to determine the best procedure. An attempt should be made to use temperatures at which popping will begin within about 1 to 1½ min.

The volume increase in popping varies greatly, but in general, good average popcorn will increase twenty to twenty-four times in volume when popped, although some of the varieties exceed this. Volume increase alone is not the ultimate goal, as quality of product is very important, particularly for the corn that is sold for use in the home or for sale by vendors. The popcorn that is mixed with sirups or other products to be packaged may be of lower quality without meeting serious objections.

VARIETIES OF POPCORN

There are two main groups of popcorn: (1) the rice type whose kernels are sharply pointed and (2) the pearl types which have smooth rounded kernels. Some agronomists consider Jap Hull-less and related varieties as a third group as they are distinct in plant and ear characteristics.

Of the rice types the principal variety is White Rice. The plants are fairly large, growing 6 to 7 ft. tall where adapted and producing ears approximately 7 in. long having 16 to 20 rows of kernels. Formerly it was grown extensively for commercial sale to the popcorn confection manufacturers, but it has now been largely superseded by other varieties.

Jap, Little Jap, Japanese, Jap Hull-less, etc., are names given to the so-called hull-less rice types of popcorn. These varieties are especially popular because of their excellent quality, producing an extremely tender product when popped. The kernels are white in most cases, although a Yellow Jap variety is grown to some extent. The plants are earlier and smaller than those produced by the White Rice varieties, averaging 5 to 6 ft. in height. The ears are small, about 3 to 4 in. long with 30 to 40 rows of sharply pointed kernels, and the yield is about two-thirds that of White Rice. Usually the price paid for this type of popcorn is enough greater to compensate for the difference in yield. In general it is most popular for small-garden and home production.

During the past two decades South American has become the most important variety of the pearl type and has almost completely displaced Queen Golden, another yellow pearl type, and White Rice, referred to

above. It is somewhat later in maturity than many other varieties and is suited to the central and southern parts of the corn belt. Popping expansion ranges from fair to good with large attractive-appearing kernels flecked with yellow.

Supergold and the very similar variety known widely in the trade under the name Yellow Pearl also belong to the smooth-kerneled yellow type and are grown to a considerable extent. They were developed by mass selection for high popping expansion from the old variety Queen Golden and are slightly earlier than South American with smaller ears and kernels. Popping expansion is high and quality very good.

Other varieties of less importance are Eight Row or Spanish, White Pearl, and Tom Thumb. The Eight Row produces a small plant with an ear possessing few rows of very wide kernels. The kernels expand greatly in popping, making it desirable for popcorn confections, although the quality is somewhat inferior. White Pearl yields kernels of low popping expansion and inferior quality. Tom Thumb with its very small ears, averaging $1\frac{1}{2}$ to 2 in. in length, is very early but of little value commercially.

Several experiment stations are doing work in the improvement of popcorn. For example, the Minnesota Agricultural Experiment Station has produced a superior hybrid Jap Hull-less type known as Minn. No. 250. It possesses superior quality and gives greater increase when popped than standard varieties.

The Purdue Agricultural Experiment Station has done considerable work in the improvement of the pearl types of popcorn. Workers at the station have been breeding popcorn by the methods which have been shown to be so valuable in the improvement of field corn. One hybrid known as Purdue No. 38, developed from Supergold and South American, has proved especially promising. A number of other hybrids are being tested, and it seems probable that the story of popcorn improvement will follow the pattern of field corn.

For commercial production a variety should be adapted and be suitable to market demands. Yellow Pearl and Jap Hull-less do well in the latitudes of northern Iowa and Nebraska but are not as suitable farther south as South American.

DISTRIBUTION OF POPCORN

Relatively few states produce popcorn commercially, with the state of Iowa alone having more than one-third of the total acreage in the United States.

In Ida and Sac counties in Iowa is found the principal popcorn acreage. Here, for example, popcorn processing companies have provided special elevators and made other inducements to the growers to produce popcorn commercially.

The price received for popcorn grown on a large scale is lower than that received by the small producer who sells directly to his customers. However, the latter method is too costly for large operations. Most popcorn is grown under contract for sale at a stipulated price, usually ranging from 2 to 3 cents per pound. The small producer who sells his product directly to his customers may at the same time receive 5 to 6 cents or more per pound, depending upon supply and demand.

TABLE 46.—AVERAGE ANNUAL PRODUCTION OF POPCORN IN PRINCIPAL STATES, 1933–1942

State	Acres	Thousands of pounds	Yield per acre, lb.
Iowa	26,638	34,469	1,248
Illinois	9,050	13,616	1,509
Ohio	8,038	13,054	1,628
Indiana	8,000	13,974	1,794
Texas	5,600	6,501	1,181
United States total	75,889	100,228	1,316

GROWING POPCORN

The person who expects to raise popcorn commercially should consider several very important problems. (1) Is his soil and environment suited to popcorn? (2) Is there a market? If he can contract either with a processing company or a local vendor of popcorn, then he is assured of his market. If, however, he depends upon locating the market after the crop is produced, he may find it impossible to dispose of the crop at a profit. The cost of marketing directly is generally expensive and usually does not offer an opportunity to dispose of very much corn. As a side line for extra cash, popcorn production has many possibilities in nearly every community.

Soils for Popcorn.—As with sweet corn, any good corn soil is suitable for popcorn. Soils that are slightly sandy but fertile may give earlier maturity, a factor of importance in most sections.

The liberal use of manures will prove profitable in most areas. Many soils respond to applications of superphosphate which may not only increase the yield but hasten maturity. Growers often apply the fer-

tilizer at the time of planting, using a fertilizer attachment. Approximately 150 to 200 lb. of 19 to 20 per cent superphosphate gives good results on average soils.

Planting and Tilling.—Popcorn is planted in check rows or drilled in the same way as field corn. Where the lister is used, popcorn is planted in this manner. It is common to place the rows somewhat closer together than with field corn, many growers planting with a 36-in. spacing, with an average of about 5 to 6 lb. of seed required to plant an acre. It is necessary to use special planter plates because of the small size of the kernels.

The hard flinty grains are not so subject to rotting in the field as dent varieties, so popcorn may be planted somewhat earlier.

It is desirable to locate the popcorn field at some distance from dent or other types of corn, or cross-pollination will occur, and this may give the corn a mottled appearance. Frequently, this is avoided by early planting of the popcorn so that it is pollinated ahead of the field corn.

Tillage operations are similar to those with field corn, with emphasis being placed on the elimination of competing weeds.

Harvesting.—In the past much popcorn has been harvested by hand, a very tedious operation at the best. With large acreages, the mechanical picker is used, thus removing one of the primary objections to growing popcorn.

Popcorn must mature thoroughly before frost to be of good quality. Ordinarily it is advisable to allow the ears to dry on the stalk as much as possible before harvest. It is also essential in most areas to store the corn in cribs that provide good ventilation. Many growers use narrow cribs or provide ventilators within the crib to ensure free movement of the air.

As soon as the corn is dried to 13 to 14 per cent moisture, it may be shelled and sold for popping. If it is to be stored for any length of time, it is better to store it without shelling. Ear corn that is properly stored may be kept for 3 to 4 years without apparent loss of quality.

Marketing.—The grower who produces under contract is relieved of many of the problems of marketing. However, one who wishes to produce for his own business may be successful if he gives the purchaser high-quality corn and establishes a good reputation for his product. In no case is it desirable for a grower to produce a large acreage of popcorn until he has made certain of his market. If he wishes to build up a specialized business, it will be desirable to start in a modest manner and create the demand ahead of the supply. In this way he may avoid the unfortunate experience of glutting the market with his product.

Review Questions

1. Why is popcorn in the same class as confections?
2. What causes corn to pop?
3. At what moisture content does corn pop best?
4. How may one change the moisture content of popcorn to bring it to the best condition for popping?
5. What are the types of popcorn?
6. Where is most popcorn grown?
7. How does pearl popcorn differ in appearance from the rice types?
8. What are the market demands for popcorn?
9. How is popcorn grown?
10. Why is it desirable to have the popcorn field isolated from the field corn?
11. Why are some types of popcorn referred to as hull-less?

References

BRUNSON, A. M., and C. W. BOWER: Popcorn, *U.S. Dept. Agr. Farmers' Bull.* 1679, 1931.

———, and G. W. SMITH: Hybrid Popcorn, *J. Am. Soc. Agron.*, **37**:176–183, 1945.

ELDREDGE, J. C., and P. J. LYERLY: Popcorn in Iowa, *Iowa Agr. Expt. Sta. Bull.* P54, 1943.

SMITH, G. M., and A. M. BRUNSON: Hybrid Popcorn in Indiana, *Purdue Agr. Expt. Sta. Bull.* 510, 1946.

CHAPTER XXI

SORGHUM[1]

Sorghum has been an important crop in parts of Africa and Asia for centuries. In those areas its grain provides food for man as well as for his livestock. Since its introduction to the United States, somewhat less than one hundred years ago, grain sorghum has become an important part of the cropping system in the semiarid regions of the country. It is widely grown in the southern Great Plains states of Texas, Oklahoma, Kansas, and New Mexico; is grown to some extent in Nebraska, Colorado, Missouri, Arkansas, and South Dakota; and is found in the irrigated valleys of California and Arizona. In Table 47 are presented the data on acreage and production of grain sorghum by states for the years 1929 and 1939.

In the semiarid regions, sorghum serves the same purpose that corn does in the corn belt, but it is grown instead of corn because it is more tolerant of heat and drought. Where corn is often a near or complete failure, sorghum has amply demonstrated its ability to produce good crops under unfavorable conditions.

BOTANICAL AND AGRONOMIC CLASSIFICATION

All the grain sorghums grown in the United States belong to the group of plants known botanically as *Sorghum vulgare* Pers. Plants of this species are coarse annuals that attain a height of 2 to 15 or more feet. The culms, or stems, consist of alternate nodes and internodes, of which there may be 7 to 20 above the soil surface. At each node a leaf arises, and these alternate on opposite sides of the stem. A bud is also located at each node, and under certain conditions it may give rise to a new shoot. When the shoots arise from buds at the lower nodes they are called *tillers*, or *suckers;* when from the upper nodes, *side branches.* The culm terminates in a paniculate inflorescence, which varies greatly in size and density.

Agronomically, *sorghum* is the common name applied to all plants belonging to the species named above. The word sorghum is used in the same sense as the words corn, wheat, oats, or alfalfa. However, the

[1]This chapter written by Robert L. Cushing, Agronomist, Hawaiian Pineapple Co., Ltd., Honolulu, Hawaii. Formerly with Cornell University, Ithaca, N. Y.

TABLE 47.—SORGHUMS HARVESTED FOR GRAIN, 1929 and 1939*

State	Acreage, thousands of acres		Production, thousands of bushels	
	1929	1939	1929	1939
Texas	1,701	2,202	23,678	25,232
Kansas	728	841	10,656	8,466
Oklahoma	748	630	8,772	5,430
Nebraska	4	356	43	3,606
New Mexico	183	177	2,858	2,500
South Dakota	1	151	5	1,290
Colorado	36	143	388	997
Missouri	30	85	376	1,647
California	73	74	1,847	2,393
All others	16	34	367	881
United States total	3,522	4,693	49,080	52,442

* Data from U.S. Department of Agriculture, *Agricultural Statistics*, 1940.

sorghums differ markedly in certain characteristics, and they are used in different ways, so it is common practice to group the varieties into four main types, as follows:

1. Forage sorghums (sorgos), which have sweet stalks and are used primarily for the production of forage.

2. Grain sorghums, which are used primarily for the production of grain and which do not have sweet stalks.

3. Broomcorn, which is grown only for its brush, used in the manufacture of brooms.

4. Grass sorghums, used mainly for the production of pasture and hay, the common type in the United States being Sudan grass.

A further separation of the grain sorghums into the types milo, kafir, feterita, etc., is sometimes made, but with the development of new varieties from crosses between types, this classification tends to break down. There would seem to be little reason why grain sorghum varieties should not be known by their variety name alone.

MARKET CLASSIFICATION

For the purpose of grading sorghum grain sold through terminal markets, the Official Grain Standards of the United States provide five classes, as follows: I, White Grain Sorghums; II, Yellow Grain Sorghums;

III, Red Grain Sorghums; IV, Brown Grain Sorghums; and V, Mixed Grain Sorghums.

Class I, White Grain Sorghums, includes all varieties of white grain sorghums and may include not more than 10 per cent of grain sorghums of other colors. There are three subclasses: A, White Kafir; B, White Durra; and C, White Grain Sorghums.

Class II, Yellow Grain Sorghums, includes all varieties with yellow and salmon-pink grain and may not include more than 10 per cent of grain sorghums of other colors. There are two subclasses: A, Yellow Milo, and B, Yellow Grain Sorghums.

Class III, Red Grain Sorghums, includes all varieties of red grain sorghum and may include not more than 10 per cent of grain sorghums of other colors. The two subclasses are: A, Red Kafir, and B, Red Grain Sorghums.

Class IV, Brown Grain Sorghums, includes all varieties of brown grain sorghums and may include not more than 10 per cent of grain sorghums of other colors.

Class V, Mixed Grain Sorghums, includes all grain sorghums not provided for in classes I to IV.

In addition to the market classes, there are five grades, indicated as Grade 1, Grade 2, Grade 3, Grade 4, and Sample Grade. The Grade designation of grain sorghum is influenced by its test weight per bushel, moisture content, content of damaged kernels, content of nongrain sorghums, and content of cracked kernels, foreign matter, and other grains. The special descriptive grade designations "bright," "discolored," "weevily," and "smutty" are used when appropriate.

THE GROWING OF GRAIN SORGHUMS

In general, grain sorghums are grown in much the same way as corn. There are, however, some special problems that arise in sorghum culture, and there are several points at which sorghum is handled differently from corn.

Varieties.—There are now approximately 50 varieties of grain sorghum grown to some extent in the United States. These differ greatly in height, time required to reach maturity, character of the stalk, head size and appearance, size and color of kernel, resistance to diseases and insects, and area of adaptation. There is perhaps no other feature of sorghum culture as important as the correct choice of variety to be grown.

Recently there have been some rather violent shifts in the relative

importance of the several grain sorghum varieties. According to a survey made in 1924 and published in 1936, Blackhull Kafir and Dwarf Yellow Milo were of about equal importance, and they were followed in order by Feterita, Hegari, White Milo, and Red Kafir.[1]

Since that time, several factors have influenced changes in the relative importance of grain sorghum varieties. (1) A number of dwarf varieties became available, and these were better suited for combine

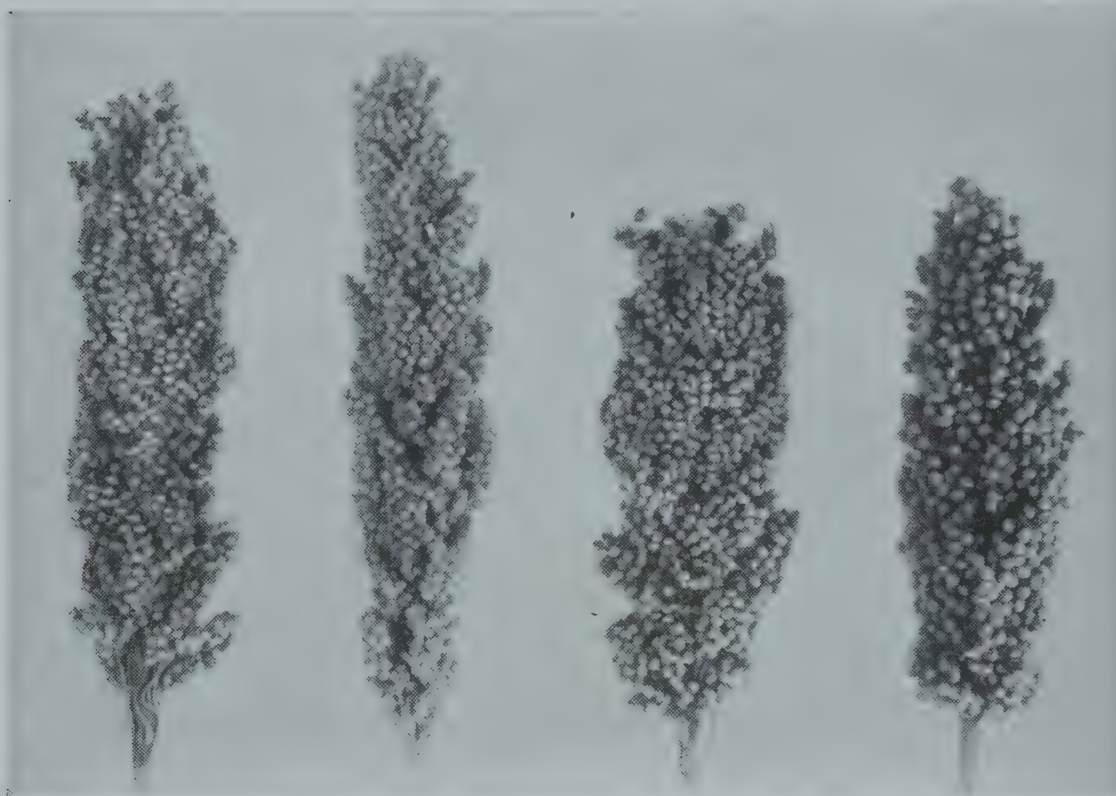


FIG. 102.—Typical heads of grain sorghum varieties. Left to right, Western Blackhull, Pink Kafir, Hegari, and Feterita. (*Courtesy of the Nebraska Agricultural Experiment Station.*)

harvesting than those previously grown. (2) The expansion of the grain sorghum area to the north was made possible by the development of new, early-maturing varieties, many of which replaced the older sorts even in the areas of longer growing season. (3) *Pythium* root rot, to which all the milo varieties grown a few years ago are susceptible, became widespread in the grain sorghum belt, with the result that there was a rapid shift to resistant varieties. Finally, it may be suggested that the continual search on the part of farmers for new and better varieties stimulated at least some of them to forsake the old for the new.

Because precise data on the acreage of each now being grown are

[1] VINALL, H. N., J. C. STEPHENS, and J. H. MARTIN, Identification, History, and Distribution of Common Sorghum Varieties, *U.S. Dept. Agr. Tech. Bull.* 506, 1936.

lacking, it is impossible to rank grain sorghum varieties in order of importance. However, the varieties listed below are all known to be used to some extent in the grain sorghum belt.

Of the varieties suitable for combine harvesting, Wheatland, Double Dwarf Yellow Milo and Beaver were the first to have wide usage. All of them are susceptible to *Pythium* root rot, and wherever this disease is present they have been replaced by resistant varieties. Somewhat

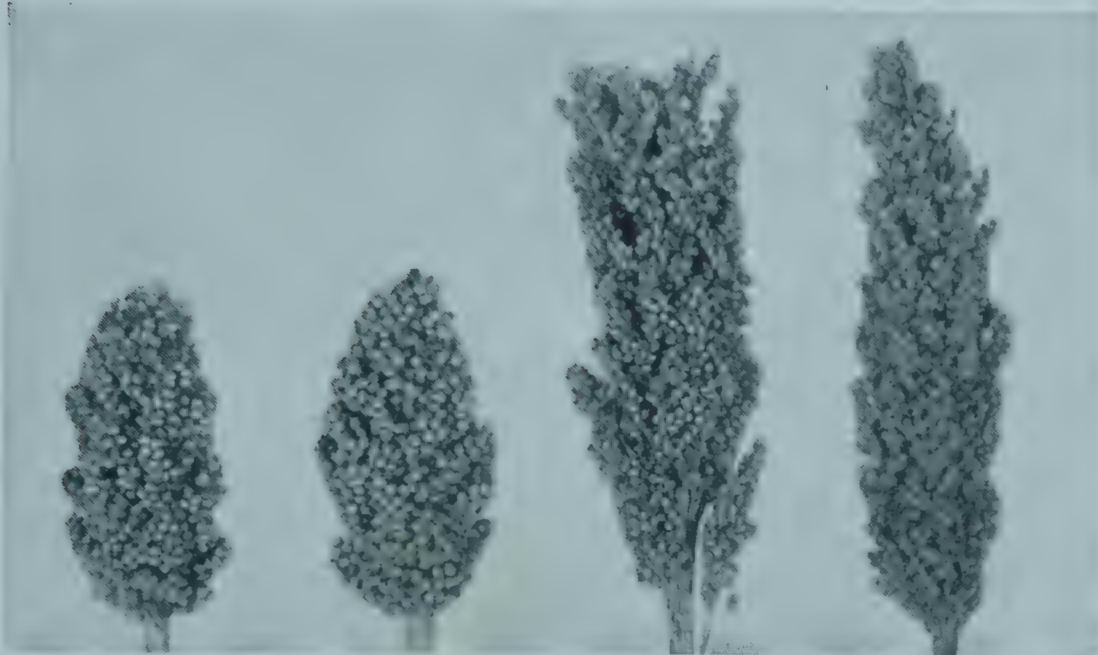


FIG. 103.—Typical heads of grain sorghum varieties. Left to right, Day, Sooner, Early Kalo, and Kalo. (*Courtesy of the Nebraska Agricultural Experiment Station.*)

later, Colby and Day were introduced as combine types for parts of Kansas and Nebraska. They are very similar, both being dwarf, early, and having rather compact heads wearing yellow grain. The new superior combine types Martin's Milo, Westland, Plainsman, Midland, Bonita, Caprock, and Double Dwarf 38 comprise the bulk of the crop harvested for grain. All these new varieties are resistant to *Pythium* root rot, an important consideration in much of the area where grain sorghums are grown.

Various strains of kafir, Hegari, and darso are still grown to some extent, but Dwarf Yellow Milo has been almost entirely replaced by the *Pythium*-resistant varieties listed above.

In the northern part of the grain sorghum region, *i.e.*, northwestern Kansas, northeastern Colorado, and western Nebraska, the early-maturing varieties Midland, Early Kalo, Sooner, Coes, Sedan Kafir, and Alliance have found favor.

It is certain that new and better grain sorghum varieties will continue to replace the old. The success of plant breeders in meeting the threat imposed by *Pythium* root rot indicates that there may soon be varieties that are resistant to other destructive disease and insect pests. Further improvement in other respects, such as better soil and climatic adaptation, resistance to lodging, and better plant and panicle types, may be anticipated. As such varieties are made available there will be changes in the list of important varieties.[1]

Seed Treatment.—Practically all the grain sorghum varieties now in wide use are susceptible to certain physiologic races of the kernel smut fungus. Kernel smut can be effectively controlled by treating the seed previous to planting with copper carbonate, Spergon, or Arasan at the rate of 2 oz. per bushel or with New Improved Ceresan at the rate of $\frac{1}{2}$ oz. per bushel.

In addition to providing control of smut, seed treatment offers protection against soil-borne seed-rotting fungi. These organisms are frequently a cause of poor field stands, and a number of experiments have demonstrated the benefits that may be derived from treatments that control them.

Seedbed Preparation and Planting.—The preparation of a favorable seedbed is particularly important in sorghum growing. The principal objectives are to promote warming of the soil, to kill weeds, and to collect and conserve moisture. Any method that accomplishes these objectives has been found to be satisfactory. Warm soil is essential for sorghum because the seed germinates poorly when the soil is cold. Weed control is important, because the young sorghum plants grow slowly at best, and a more thorough job of weed killing can be done before planting than after the small seedlings have emerged. Finally, most of the sorghum is grown in regions where moisture conservation must usually be practiced to the fullest extent in order to ensure an adequate supply for the growing crop.

Since most sorghum grown for grain is planted with a lister, this implement is the one generally used in seedbed preparation. While a number of experiments have indicated benefit from fall or winter tillage, most growers begin seedbed preparation in the spring, after weed growth has started. At that time the land may be disked, plowed, or blank listed. When weeds start to grow again, following the first tillage operation, any one of a number of practices may be used. If the land was first disked, a common procedure is to list and plant in the same oper-

[1] MARTIN, JOHN H., Breeding Sorghums for Social Objectives, *J. Heredity*, 36:99–106, 1945.

ation. This is an economical method and is widely used, but it does not always give the best results. If the land was first blank listed, the second operation may consist of "throwing in" the ridges, in which case the original furrows are reopened at planting time. As judged by field stand and yield of grain, this method has been found to be the most desirable, particularly when the blank listing is done in the fall or very early spring.[1] Another variation of this method is to "split" the ridges. In this operation the furrows made by the second listing are located where the ridges were thrown up by the first.

Where the lister is used in the final operation of seedbed preparation, planting is done with the lister. Occasionally, sorghum is surface planted on land that has been plowed, and often in such cases the planter is equipped with disk furrow openers.

Date of Planting.—Since sorghum is a hot-weather crop it should not be planted too early in the spring. Early planting often results in poor field stands and lowered yield of grain. The optimum date of planting varies with location and from year to year, but, in general, it is good practice to plant sorghums about 10 days after the usual time for planting corn. An exception is found in those seasons and areas where chinch bugs are a threat. In such situations, planting as early as possible is advisable.

Rate of Planting.—The optimum spacing of sorghum plants in the field is governed largely by the variety being grown, the use that will be made of the crop, and the location where it is being grown. To illustrate, some varieties, such as Dwarf Yellow Milo, tiller profusely in thin stands, while other varieties do not. Tillering varieties can therefore be grown successfully in wider spacings than nontillering ones. Sorghum grown for forage is commonly planted much thicker than when it is being grown for grain. Thick planting not only results in a greater total crop yield, but the stems are finer and more palatable as livestock feed. Finally, spacings may be much closer in those areas where there is normally an adequate supply of moisture from rainfall, or where irrigation water is available, than in the very dry regions.

In the grain sorghum area, where the crop is commonly grown in rows 40 or 42 in. apart, plants of dwarf varieties, and taller varieties that do not tiller, should be spaced 4 to 6 in. apart in the row. In very dry regions, spacings of 8 to 10 in. are generally more satisfactory. Varieties that tiller profusely can be spaced 12 to 18 in. with no reduction in grain yield under average conditions.

[1] Laude, H. H., and A. F. Swanson, Sorghum Production in Kansas, *Kans. Agr. Expt. Sta. Bull.* 265, 1933.

The amount of seed that must be planted to provide an optimum spacing varies with a number of factors. Seed size of sorghum varieties differs greatly, and it is obvious that more pounds per acre will need to be planted when the seed is large than when it is small. It is equally apparent that more seed is required when viability is low than when it is high, and the same is true when the seedbed is wet and cold instead of being in favorable condition to promote rapid germination. Under average conditions, with seed about the size of that of Early Kalo, 2½

FIG. 104.—Harvesting grain sorghum with a row header attached to the side of a wagon and driven from a rear wheel. (*Courtesy of the Nebraska Agricultural Experiment Station.*)

to 3 lb. of seed per acre will give a field stand of two plants per foot of row.[1]

Harvesting.—One of the principal objections to sorghum as a grain crop has been the difficulty of harvesting it conveniently and economically. A method of long practice was to cut the mature heads from the standing stalks with a knife and toss them into a wagon drawn through the field. This procedure is essentially the same as husking corn from the standing stalks, and it is equally laborious and time-consuming. As dwarf erect-headed varieties and improved machinery became available, hand heading ceased to be widely practiced, and combining became the prevailing method of harvesting. A few other machine methods of harvest also are used.

Harvesting with a corn binder is a satisfactory method, particularly where high-quality grain is desired, or where the forage is to be utilized.

[1] CUSHING, R. L., T. A. KIESSELBACH, and O. J. WEBSTER, Sorghum Production in Nebraska, *Neb. Agr. Expt. Sta. Bull.* 329, 1940.

After binding, the bundles are placed in shocks until the grain is dry enough to thresh. In the case of shorter varieties the entire bundle may be run through the thresher. Some varieties, however, have stalks so long and so retentive of moisture that it is not practicable to do this. With such varieties, the heads are commonly cut from the stalks at the time of threshing and only the heads are put into the machine. There are a number of ways in which this may be done, but one that has

Fig. 105.—A field of Wheatland, a dwarf variety of grain sorghum suitable for combine harvesting. (*Courtesy of the Fort Hays, Kansas, Agricultural Experiment Station.*)

recently become popular involves the use of a combine with a vertical sickle. Ordinarily the combine is moved from shock to shock, the bundles are placed one at a time in position so that the vertical sickle cuts off the heads, the heads are conveyed directly to the cylinder, and the bundles of stover are either reshocked or hauled to a central point for stacking.

Machine heading is still practiced to a slight extent, and there are two types of headers that may be used. One is the regular wheat header, which can be readily adapted for heading sorghum. The other is a specially designed one-row header which attaches to the side of a regular farm wagon and is driven by a chain and sprocket from one of the rear wheels. When the heads have been harvested, they are usually piled in ricks 3 or 4 ft. high and 5 or 6 ft. wide at the bottom. In order

to avoid as much spoilage as possible, the ricks are generally located on well-drained soil and preferably are piled on sod or stubble or on a layer of cut sorghum stalks. After 10 days to 2 weeks of curing in the rick, the grain is dry enough to be threshed.

With the advent of combine harvesters and dwarf varieties, combining appeared to offer the ideal solution to the problem of harvesting sorghum. But, while the method is widely used, there are certain precautions that must be observed in order to do a satisfactory job. The stalks and leaves of sorghum remain green and full of moisture, even after the grain is fully mature. This means that in the northern half of the Great Plains the crop cannot safely be harvested with a combine until after the plants have been killed by frost and the grain has had an opportunity to become thoroughly dried. Ordinarily, only the dwarf varieties that are exceedingly resistant to lodging can be handled in this way, since most varieties lodge badly under such treatment. Even when the harvest has been properly conducted, grain put in storage directly from the combine must be observed closely, and often special handling is necessary to prevent spoilage.[1]

GRAIN SORGHUM IN THE ROTATION

It has long been the opinion of farmers that sorghum is "hard" on the land, and this belief has been partially borne out by experimental evidence Yields of some crops are sometimes lower following sorghum than following corn. In semiarid regions this results largely from soil-moisture depletion. Sorghum commonly continues growth much later in the fall than corn, it has a more extensive and finely divided root system, it usually yields a greater tonnage of total crop, and for these reasons it leaves less water for the succeeding crop than does corn. However, even where abundant irrigation water is available, the yield of some crops is lowered following sorghum, so, in addition to moisture depletion, other factors must be involved. Probably the most important of these is the temporary nonavailability of nitrates. It requires somewhat longer for soil microorganisms to decompose the stalks and roots of sorghum than of corn. As a consequence there is a temporary tie-up of nitrogen, and this may have an adverse effect on the succeeding crop. This effect can be wholly or partly overcome by applications of nitrogenous fertilizers in irrigated regions or by following sorghum with fallow in the semiarid regions.

Rotations with sorghums have not been worked out experimentally

[1] Martin, John H., L. A. Reynoldson, B. E. Rothgeb, and W. M. Hurst. Methods of Harvesting Grain Sorghums, *U.S. Dept. Agr. Tech. Bull.* 121, 1929.

on an extensive scale and, indeed, the crops grown coincidentally with sorghum are not well suited for combination in a rotation with it. In the southern Great Plains, where most of the sorghum is grown, the other principal crops are wheat and cotton. Where wheat and sorghum are grown on the same farm, the sorghum crop is not harvested in time to sow wheat; hence the common practice is to follow wheat with wheat and sorghum with sorghum. Where summer fallow is a desirable practice, a rotation of wheat, sorghum, and fallow is a common procedure. The clean tillage following sorghum permits the accumulation of soil moisture and nitrates, while sorghum does well following wheat. In some parts of the grain sorghum belt a sequence of wheat, sorghum, and spring barley is a satisfactory way of changing a field from sorghum to wheat.

In the Texas and Oklahoma areas where cotton is the important cash crop, cotton and sorghum are generally not planted in rotation. Cotton yields from continuous cropping are higher than those of cotton following sorghum, while the sorghum does reasonably well following sorghum.

Since most of the grain sorghum crop is grown on fertile soils in semi-arid regions, there is little need for the use of fertilizers. Barnyard manure may sometimes be used with benefit, particularly in the irrigated regions.

USES OF GRAIN SORGHUM

Most of the grain sorghum crop is used for livestock feed on the farm where it is produced. It is estimated that, during the period 1930–1941, 85 per cent of the crop was consumed in this way. An insignificant amount, probably not exceeding 1 to 1½ per cent, is saved for seed. Of that portion of the crop which is sold, an appreciable amount is probably purchased and used by neighbors of the producer, although some of it eventually reaches the terminal markets. Most of this latter is used in the production of mixed feeds, especially for poultry.[1]

In general, sorghum grain is considered to have 90 to 95 per cent the feeding value of corn. Chemical analyses have indicated that sorghum grain is, on the average, slightly higher in protein and slightly lower in fat content than corn, while the carbohydrate content is about equal. When it is supplemented with feeds that provide the necessary amounts of protein, calcium, and vitamins A and D, grain sorghum is good feed for all classes of livestock.

[1] Edwards, W. M., and J. J. Curtis, Grain Sorghums, Their Products and Uses, *U.S. Dept. Agr. Northern Regional Research Lab.*, ACE-193, NM-229, 1943.

Because the kernels are small and because those of some varieties are hard, the grain should be ground for all classes of livestock except sheep and poultry.

While sorghum grain provides a staple part of the diet for people in certain parts of the world, and while it was sometimes used for food by early settlers in the Great Plains region, practically none of it is used directly in this way at the present time. One result of the Second World War, however, has been the development of a food product from a certain type of sorghum starch, and this industry promises to continue. Starch from the cassava plant has been used in the past to make tapioca. The chief source of supply, the Dutch East Indies, was lost to the enemy early in 1942. Naturally, the users of cassava starch began a search for a domestically produced substitute. This they found in certain varieties of corn and sorghum which possess a type of endosperm known as *waxy*. It was found that starch made from the grain of waxy sorghum or corn has many properties similar to those of tapioca starch. Since a satisfactory food product can be made from starch of waxy sorghum and corn, there is a demand, though it is limited, for these grains. Large quantities of grain sorghum were used for the manufacture of industrial alcohol, whisky, beer, and starch during the Second World War.

DISEASES AND INSECT PESTS

The more important diseases of sorghum are the loose and covered kernel smuts, heat smut, and *Pythium* root rot.

Covered kernel smut, caused by *Sphacelotheca sorghi*, and loose kernel smut, caused by *S. cruenta*, are rather similar in appearance. In each case, the sorghum kernel is replaced with a mass of dark-brown to black spores enclosed at first within a thin whitish to brownish membrane. When the membrane breaks, the spores are liberated and are wind-borne to healthy kernels on surrounding heads. Unless the spores carried on a kernel are killed, they may cause infection of the plant resulting from the germination of the kernel. Effective control may be secured as described under the section on seed treatment.

Head smut, caused by *Sphacelotheca reiliana* (formerly *Sorosporium reilianum*), attacks the entire head, leaving only a mass of black spores. This disease lives from one growing season to the next in the soil, and seed treatments are ineffective in controlling it. Fortunately the losses from head smut are not so great as those from the kernel smuts.

The root rot caused by *Pythium arrhenomanes* has been mentioned previously as a destructive disease in the southern Great Plains. Like

head smut, it is soil-borne and seed treatments are ineffectual. But great success has been attained in developing resistant varieties, and it appears that damage from this disease can be minimized by proper choice of the variety to be grown.

Probably the greatest losses of sorghum from insect injury are caused by the chinch bug. This insect migrates from small grain fields, before or as they are being harvested, to fields of young sorghum plants. Their feeding may completely kill or severely damage the sorghum. No variety is immune to chinch bugs, but kafirs and some varieties with kafir parentage are resistant. Next to the use of resistant varieties, the most effective control is to block, by means of one of the several methods available, the migration of the bugs into the sorghum field.

SORGHUM POISONING

All sorghums are capable of producing sufficient prussic (hydrocyanic) acid to cause the death of livestock when pastured under certain conditions. The poisonous compound is found largely in the leaves of the young plants, but young suckers and branches on large plants are equally dangerous. Grain sorghums and sorgos are generally much more toxic than Sudan grass. There is, however, apparently no danger of loss from feeding sorghum grain or well-made sorghum hay and silage.

Review Questions

1. In what parts of the United States is sorghum most widely grown for grain?
2. Since sorghum is cultured in much the same way as corn and the crop is used for the same purposes, why is not corn grown in these regions?
3. What factors must be considered in choosing a variety of sorghum?
4. Why might a variety perfectly adapted to the Gulf Coast of Texas be unsuitable in South Dakota?
5. While the operations involved are generally similar, a well-prepared seedbed is even more important for sorghum than for corn. Why?
6. What general rule may be followed in regard to the best time of planting sorghum?
7. What things must be taken into consideration in determining the rate of planting for sorghum?
8. What three general methods are there for harvesting grain sorghum?
9. Why are certain difficulties encountered in harvesting sorghum with a combine that are not found in harvesting wheat by the same method?
10. What relationship is there between the facts that sorghum is more drought resistant than corn but is "harder" on the land?
11. Work out suitable rotations, including grain sorghum, for (*a*) west Texas, (*b*) south central Kansas, and (*c*) southwestern Nebraska.
12. Keeping in mind the cultural requirements of sorghum and the uses to which the crop is put, describe the type of farming in which sorghum would seem to be best suited.

13. Why can the kernel smuts of sorghum be controlled by seed treatment while it is impossible to control head smut in the same way?

14. In some regions, where both corn and sorghum can be grown but in which sorghum will, on the average, give a greater return per acre, farmers prefer to grow corn. Can you suggest reasons for this?

References

BRANDON, J. F., J. J. CURTIS, and D. W. ROBERTSON: Sorghums in Colorado, *Colo. Agr. Expt. Sta. Bull.* 449, 1938.

HUME, A. N., and CLIFFORD FRANZKE: Sorghums for Forage and Grain in South Dakota, *S. D. Agr. Expt. Sta. Bull.* 285, 1934.

KARPER, R. E., J. R. QUINBY, D. L. JONES, and R. E. DICKSON: Grain Sorghum Varieties in Texas, *Tex. Agr. Expt. Sta. Bull.* 459, 1932.

KILTZ, B. F., J. B. SIEGLINGER, W. M. OSBORN, B. F. BARNES, and H. H. FINNELL: Sorghums for Grain and Forage, *Okla. Agr. Expt. Sta. Bull.* 210, 1933.

LAUDE, H. H., and A. F. SWANSON: Sorghum Production in Kansas, *Kans. Agr. Expt. Sta. Bull.* 265, 1933.

MARTIN, J. H., J. S. COLE, and A. T. SEMPLE: Growing and Feeding Grain Sorghums, *U.S. Dept. Agr. Farmers' Bull.* 1764, 1936.

SWANSON, A. F., and H. H. LAUDE: Sorghums for Kansas, *Kans. Agr. Expt. Sta. Bull.* 304, 1942.

CHAPTER XXII

MARKETING OF GRAIN CROPS

As the agriculture of our country ages, it becomes more and more evident that the successful farmer must not only be trained in the production of crops and livestock, but he must also develop greater ability to understand certain fundamental principles of economics, particularly as these relate to the marketing of farm products. Not every farmer is concerned with the details of marketing, but those who have an understanding of principles will be in a much better position to dispose profitably of grain raised on the farm. In the present discussion, major attention will be given to problems relating to the marketing of grain, as grain, and not in the converted forms of livestock products.

WHEN SHOULD A FARMER MARKET GRAIN?

The answer to this question is not always simple. In some areas farmers produce grain crops entirely for the cash market and do not raise livestock; therefore, in such cases, the farmer who sells his grains directly will regularly dispose of his crops on the cash market.

Some grains, particularly such crops as flax, are grown almost exclusively for the cash market. Others, including most of the grains, may be used either for sale on the market or fed to livestock. Examples are corn, oats, wheat, barley, rye, and soybeans. As a rule most of the wheat produced in this country is sold to be processed into flour. However, some wheat is fed to livestock and poultry, especially in those areas where relatively little wheat is grown or it is not especially suited for flourmaking and where it serves as a substitute for other feed grains.

Even the general farmer who raises livestock may market a greater proportion of his crops in certain years than in others. For example, when the demand for grain is especially great and the market prices are high, it may be advantageous for some farmers to sell relatively more in the form of grain and to feed somewhat less to livestock. In some years high-grade malting barley may be of such value that it is not economical to feed it. The grower who watches the market reports is in a position to take advantage of these situations and to shift his plans accordingly.

In many of the heavy corn-producing areas, it is not uncommon for the farmer to harvest more grain than he can utilize in his feeding oper-

ations. Under these conditions he may market a part of the crop, retaining only the proportion that he will be able to feed within the year. In some years it is best to sell the grain as soon as harvested, while at other times it pays to store for later sale. Since no hard and fast rule can be followed, each grower should reach his decision on the basis of all available facts. Even with all available information he may often find that he made the wrong decision, as unusual climatic or economic factors may greatly change the market prices.

Fig. 106.—Plains Equity Exchange and Cooperative Union, Plains, Kansas. (*Courtesy of Harold Hedges, U.S. Department of Agriculture.*)

MARKETING PROCESSES

The average farmer does not produce grain in sufficient quantities to permit him to market it directly, but he usually sells through local dealers. In most cases these dealers operate elevators of various types.

Types of Elevators.—The principal types of country elevators are (1) farmers' cooperatives, (2) independent, (3) commercial line, and (4) mill.

The farmers' cooperative elevators are owned by local people who purchase stock in the enterprise. The cooperative employs a manager who buys and sells the grain and keeps the records of the organization. At the end of the year it is common to declare a patronage dividend, which is paid to the various stockholders. In some sections of the country elevators of this type handle a major part of the grain.

Many elevators engage in various side lines such as the marketing of coal, fertilizer, or twine.

The independent elevator is owned and controlled by one or more persons in a community, in much the same way as a store or bank. The object is to offer the marketing service to the community on a basis that will permit a profit to the operator. These elevators generally are not so common as the cooperatives.

Line elevators are commonly operated by large organizations which may own many elevators in several different states. In most sections these elevators are probably the principal competitors of the farmers' cooperatives. The line elevator operates in much the same manner as the other types.

Mill elevators are elevators operated by milling companies primarily for the purpose of obtaining the grains needed for their own operation. This type of elevator is not nearly so important as the others as it is more limited in its scope.

Brokers or Commission Houses.—These organizations serve a very important place in marketing. Their principal functions are (1) to sell grain on consignment, charging a small commission on the transaction; (2) to finance country elevators; and (3) to inform their clients as to market demands and trends.

Although most of the grain is shipped to the terminal markets by elevator companies, a private operator may market his grain through a commission house. The firm samples the grain, places it on sale, and sells to the highest bidder. A charge is then made against the shipper for the services rendered. In effect, the commission firm acts as an agent for the shipper. Most farmers do not market their grain in this manner but usually deliver it to a local elevator.

FIG. 107.—Processing plant for hybrid seed corn and other grains, Pennsylvania Farm Bureau Cooperative Association, Manheim, Pennsylvania. *(Courtesy of Harold Hedges, U.S. Department of Agriculture.)*

GRAIN INSPECTION

In 1916, the United States set up a system of Federal supervision for the grading of commercial grains. For most of the grains, rules and regulations have been made to make certain that both the buyer and the seller are protected. The work of the Federal employees is supervisory in nature, and they are not charged with the responsibility of grading the grain that comes to market.

In every city where considerable grain is marketed, the grain is sampled and inspected by state employees who are licensed by the Office of Federal Grain Supervision and are bound by their rules and regulations. As soon as a car reaches the market, a representative sample is taken for the determination of the grade. In rush seasons, samples are often taken at railroad division points and sent into the market ahead of the car so that the grade may be determined without delay.

Although the actual grading is done by the state inspectors, the seller or the purchaser may appeal to the Federal supervisor for a check

on the grade. The Federal employees then take samples and determine the grade independently of the state inspector, and their decisions must be accepted by the state. Many commission firms take samples of their own and determine the grades. If it is believed that the grade as determined by the state inspector is incorrect, the firm appeals to the Federal supervisor for a regrade.

HOW GRAIN IS SOLD

It is of interest to follow an ordinary transaction in the sale of a carload of grain. For example, an elevator operator purchases a carload of shelled corn. The price he pays to the farmer will depend upon the price being paid at the terminal market to which he will ship the corn. This price will vary according to the market grade of the corn. In many years the corn will have a high percentage of moisture, which will lower the grade and consequently the price that will be paid on the market. The elevator operator will get a report from the terminal market on the price being paid for corn of the grade that corresponds to the corn being purchased. He will compute the cost of shipping the grain to the market, allow for possible losses in handling, costs for storage, and an amount for his own services. The total of these costs will be deducted from the terminal market price and will determine the price paid locally. As a rule, each day the local elevator receives from the terminal market a report that serves as a basis for determining the price he will offer for grain delivered to his elevator.

It is evident that the price may change greatly from the time the corn is purchased in a community until it reaches the terminal market. It is possible for the operator to protect himself against market fluctuations through a type of insurance known as *hedging*. To understand hedging it is necessary to consider how the market operates a system of futures.

Futures.—The two types of marketing are *cash* and *futures*. The future market involves the setting of a price on a given grade of grain for delivery at a future date. The common futures are May, July, September, and December, although contracts for delivery are permissible in any other month. These four future dates were selected in part because July and September correspond to the early movement of the new crops of winter and spring wheat, December marks the beginning of the movement of the new corn crop, and May marks a period for the clean up of the wheat and considerable corn.

Reference to the grain-market pages in a local paper will show prices for cash grain and for the futures as indicated. Usually the price for

the future will be enough higher than the cash market to allow for the costs of storage. Theoretically, as the days pass, the cash market and the future market prices come closer and closer together until they are the same.

Speculators in grain often deal in grain futures as a possible source of profit. If the speculator believes that the price of a given grain such as corn will be sufficiently high in the future to return a profit, then he will purchase corn on the future market. For example, suppose that on Mar. 1 the speculator decides that it will be profitable to buy corn for sale in July. He may call a broker and buy a contract for the delivery of a given number of bushels of corn in July at the price listed that day. Suppose that the price on Mar. 1 of the July future is $1 per bushel. As the season progresses, the price of the July future may change because of various factors. If the price of the July future rises, the speculator may sell his contract at the higher price and thus make a profit. It is evident that the reverse may happen; if the price falls, he will sell his contract at a loss. In neither case did he have any intention of obtaining any corn. He was operating somewhat as a gambler, pitting his judgment against the economic shifts that might occur.

Hedging.—The elevator manager may use the futures market to advantage as a price insurance against fluctuations in the market. For example, a local farmer may bring to the elevator 1,000 bu. of wheat, and he wishes his money at once. The elevator operator may wish to hold the wheat for several weeks, and in the meantime the price may vary greatly. Theoretically, there is as much opportunity to lose as to gain. Accordingly, to protect himself, he sells 1,000 bu. of wheat on a future contract. Again, in the month of March, he may contract to sell 1,000 bu. of wheat for May delivery. The price on the day of the transaction may be as follows:

Cash market....................	$1.00
May future......................	$1.10

Within a few days the dealer receives more wheat and decides to ship a car to the terminal market. The wheat reaches the market 2 weeks after the original purchase from the farmer. In the meantime the market price has changed. Suppose that the cash price of wheat has dropped 5 cents per bushel. In this case, the dealer would sustain a loss of 5 cents per bushel, or $50 on the 1,000 bu. However, if the cash price has dropped, so has the futures price. Theoretically, the May future would be $1.05. When he ships the grain, he picks up the future contract, as he will not deliver the grain in May, having sold it. The

broker will pay him 5 cents profit on each bushel, since he has gained in this transaction. To illustrate:

Cash price, Mar. 15	$0.95, loss of 0.05 per bushel
May future, Mar. 15	1.05, profit of 0.05 per bushel

The two transactions balance, and the price insurance has been effective.

The alternative would be for the price of the cash market to be 5 cents higher. In this case he would profit 5 cents per bushel on the cash deal, but when he picked up his futures contract he would lose 5 cents, as it would be $1.15 per bushel.

Cash price, Mar. 15	$1.05, profit of 0.05 per bushel
May future, Mar. 15	1.15, loss of 0.05 per bushel

The two examples illustrate how the operator may guard against speculation and may operate his business as a service enterprise. In many cases the operator is a manager representing an organization, and as such he is concerned only with operating the elevator in a business-like manner, leaving the speculation to others.

CORN-HOG RATIOS

Since corn production and hog raising are so closely related, the price of one usually follows the price of the other. On an average on the Chicago market, it takes between 11 and 12 bu. of No. 2 corn to equal the value of 100 lb. of live hogs. Sometimes the ratio varies so that as many as 15 to 16 bu. or more of corn is required to equal the market price of 100 lb. of live hogs. As corn becomes lower in price in relation to the price of pork, there is a marked tendency to breed more sows and to bring about an overproduction of pork; when the supply of hogs is large in relation to the supply of corn, the price of corn tends to rise relative to the price of hogs and the ratio becomes narrower.

Many of the factors affecting corn and hog prices are beyond the control of the farmer. Probably in general the average farmer who feeds hogs will find it advisable to practice regular feeding and not to attempt to get into and out of pork production. Experience has shown that many farmers make adjustments in livestock production at the wrong time. The farmer who keeps some livestock each year is in a favorable position to utilize the soft corn crops that occur at intervals throughout the corn belt.

Review Questions

1. What factors should a farmer consider in determining whether to feed or sell his grain for cash?

2. What are the types of elevators?
3. How does each function?
4. What types of elevators are found in your community?
5. List the services provided by your elevator?
6. What are the functions of a commission house?
7. How does the grain-inspection work aid marketing?
8. What are grain "futures"?
9. Explain hedging, using examples of the operation.
10. How can a farmer make use of the futures markets?
11. What part does the speculator play in grain marketing?
12. What is meant by the corn-hog ratio?
13. From current newspapers determine the present relationship between hog and corn prices.
14. Why should every farmer know a few of the fundamental principles of marketing?

References

LONG, T. E., and M. C. CROPSEY: Grain Storage on the Farm, *N. D. Agr. Expt. Sta. Bull.* 302, 1941.

ROBOTKA, F., and R. C. BENTLEY: Cooperation in Grain Marketing in Iowa, *Iowa Agr. Expt. Sta. Research Bull.* 276, 1940.

SMYTHE, L. T., and C. R. HOGLUND: Feed-grain Price Relationships in South Dakota, *S. D. Agr. Expt. Sta. Bull.* 367, 1943.

WALLACE, B. A., and J. I. FALCONER: Farmers' Elevators of Ohio, *Ohio Agr. Expt. Sta. Bull.* 650, 1944.

CHAPTER XXIII

IMPROVEMENT OF GRAIN CROPS

In the earlier chapters, consideration has been given to the problems of growing and marketing the grain crops. Some reference has been made to breeding as it related directly to the problem under consideration. Because of the importance of the subject it seems appropriate to conclude the study of grain crops with a detailed consideration of methods of improvement and their significance in grain-crop production.

State and Federal experiment stations and some commercial seed companies are conducting active programs of plant breeding. Generally, the staffs of these agencies consider the needs of the grower and consumer, the characteristics of all available varieties of plants being studied, and proceed to plan programs designed to develop varieties that are superior in the greatest possible number of desirable characters.

The successful plant breeder should understand the laws of genetics, the mode of inheritance of differential characters of the crop plants with which he is working, their general physiology, the biology of important disease organisms, and the pests likely to attack the plant. In breeding for disease and insect resistance, the cooperation of the plant pathologist and entomologist in producing artificial epidemics of particular diseases and in inducing infestations is of great value. When quality problems are considered, as in wheat breeding, it is necessary to enlist the aid of the cereal technologist. In most cases it is desirable to work closely with a soils scientist, since varying levels of fertility may result in widely differing responses. Where unusual cytological behavior in wide crosses requires fundamental studies of the cytological causes of variability, the aid of the cytogeneticist may help to overcome difficulties. Modern cytogenetic techniques may be used also when it is desired to combine the characters of species and varieties that differ widely in chromosome numbers or nature. In many cases a knowledge of taxonomy and ecology may be essential in planning an improvement program or in making the final selection of the desired characters.

In every state extensive varietal trials of available and new varieties are being conducted constantly to determine which varieties are best suited for the particular conditions prevailing. With a well-coordinated

program, the extension service acts upon the information made available by research and carries it to the producer.

MODE OF REPRODUCTION

The mode of reproduction of the crop plant is of first importance to the breeder. Hayes and Immer[1] have divided the crop plants into sexually and vegetatively reproduced groups based on their modes of reproduction. The sexual groups have been subdivided according to mode of pollination:

Naturally self-pollinated: Oats, wheat, barley, flax, rice, and soybeans
Often cross-pollinated: Sorghums
Naturally cross-pollinated: Corn and rye

There is a close relation between mode of pollination and methods of breeding, as will be evident from studying definite breeding methods. As will be indicated later the method of pollination makes necessary very different modes of attack in plant improvement.

NEED FOR IMPROVEMENT

The layman may well raise the question as to why it is necessary to improve our crops. The answers are obvious to anyone who has observed crops in the field. Each farmer appreciates the differences in the yielding ability of varieties or how one variety of small grain may be severely injured by diseases such as rust while another variety may suffer little or no damage. Too often, however, the grower fails to understand the reason for the differences and may attribute differences in performance to the variety used, when environmental conditions alone may be responsible for differences in yield. Differences in disease reaction may in some cases be due to escape from, rather than ability to resist, the disease.

A list of the needs for plant improvement is to some extent a recital of existing weakness. While progress has been made, there is great need for further work. Although the problems are similar for several of the crops, it is well to consider them by species.

The Wheats.—All the wheats are subject to several important plant diseases; so the breeder is likely to find the control of these among his primary problems. The more important diseases of wheat are black stem rust, leaf rust, scab, black chaff, the smuts, and various root rots.

It is well to understand that plant pathogens are composed of physiologic races that may be differentiated only by the manner of reac-

[1] Hayes, H. K., and F. R. Immer, "Methods of Plant Breeding," McGraw-Hill Book Company, Inc., New York, 1942.

tion on a series of differential host varieties or species in their control. These races are much the same as strains of crop plants. Fortunately not all races are prevalent at any one time in a given locality. For this reason an apparently resistant variety may be susceptible to a race that does not occur in a given section. However, there is always the danger that the race to which the variety is susceptible may become present in epidemic form and thus do great damage. This has happened in the past and has resulted in the replacement of varieties. There exists the ever-present threat of the development of new races to which an otherwise resistant variety may prove susceptible. It is evident that the breeding program should include a careful study of the genetic basis of disease resistance both in the host plant and in the disease organism and a consideration of physiologic races, their stability, pathogenic relationship, and method of origin.

Certain agronomic characters are to be desired in improved varieties of wheat. Yield, the result of many factors, is of great significance, and increases are generally sought by the breeder. Strength of straw, desirable kernel type, and resistance to shattering are important agronomic characters. All are conditioned by genes under particular environmental conditions which may modify their expression.

The bread wheats are studied as to the quality of the flour that they yield, since this factor alone will determine their market suitability. In some cases the color of the flour may be yellow; in others it may be gray. Regardless of how well a variety may yield, it must meet the demands of the miller and the baker.

Winter Wheat.—One of the most evident needs is greater winter hardiness. This is a complex problem and receives the attention of the breeder of both the hard and the soft red winter wheats. Disease resistance is of equal importance. In the soft red winter wheat area generally, it is desired that the kernel be soft, not hard and flinty like the desirable types of hard red winter.

Spring Wheat.—An important accomplishment of the breeder has been the development of varieties resistant to black stem rust. This was accomplished by crossing resistant varieties of *durum* and *emmer* with *vulgare* wheats and selecting for resistance and the *vulgare* type. Most spring wheat varieties now grown in the spring wheat area of the United States and Canada are resistant to stem rust. These wheat varieties have resistance under field conditions from heading to maturity, to all or nearly all prevalent races of rust, although they are susceptible to certain prevalent races in the seedling stages. The wheat breeder in cooperation with the plant pathologist is studying rust reaction under

controlled experimental conditions, in the greenhouse and in the field, and adding by breeding, whenever possible, physiological resistance to particular races of rust in the mature plant; resistance that has been used so extensively in the spring wheat region.

Resistance to other diseases, such as leaf rust, the smuts, and scab is of primary importance.

Superior grain and milling qualities are essential if a variety is to be satisfactory. Because of their rather limited production and specialized uses, these wheats must meet the very exacting requirements of the flour trade if the variety is to be accepted by the milling industry.

Oats.—The oat, like wheat, is subject to many diseases, particularly stem and crown rust and the smuts. Some of the most notable progress has been made in the control of these diseases by breeding such varieties as Vicland, Tama, and Clinton, which are resistant to all three diseases. Great progress has been made also in combining the desirable characters of Victoria and Bond, which carry resistance to crown rust and the smuts with the characters of standard stem rust resistant varieties. New selections excel also in agronomic characters, including resistance to lodging and weight per measured bushel. The progress in oat improvement of the last decade is worthy of special emphasis. Even today many farmers are growing varieties that lack resistance. As with wheat, there is need for increased yielding ability and other agronomic characteristics, particularly improved kernel type with a lower percentage of hull, and an increased bushel weight of the grain.

Barley.—This crop is subject to many diseases, and the agronomic qualities may be improved greatly. The barley grown for malting purposes must be suitable for the production of high-quality malt if the variety is to be successful. An important phase of most improvement programs in the regions where malting barley is grown is devoted to testing the malting quality of the more promising selections. Crosses are made to combine malting quality with desirable agronomic characters.

Rye.—In general, rye is not subject to so many diseases as the other small grains, but there is need for improvement in the quality of the grain. Many varieties are badly mixed in kernel type. It is possible that palatability might be improved, making rye a more satisfactory feed crop than it is at present.

Flax.—Much work has been done to control flax diseases, and flax could not have been grown satisfactorily without the development and use of wilt-resistant varieties. Notable progress has been made in breeding rust resistant varieties, and the information available makes it seem feasible to produce varieties of flax that are resistant to all physiologic

races of rust. Further studies are needed to determine the extent to which pasmo may be controlled by breeding.

In various crosses it is often necessary to cross a variety that contains some important character but lacks either in oil content or quality with a variety that excels in oil quality and oil content. Selection for these characters, therefore, is a major part of most flax-improvement programs.

METHODS OF IMPROVEMENT

The plant breeder may follow one or more of three general methods of improvement: (1) introduction, (2) selection, and (3) hybridization.

Introduction.—This is an old method based upon the simple practice of introducing into a state or region a variety developed in another area. In some cases an introduced variety may be used directly in a new region. Noteworthy examples are Kherson oats and Turkey wheat from Russia. Today, through the splendid cooperation between states, varieties developed in one state are tested in another. Oats developed by hybridization, such as Vicland, Tama, and sister selections, are worthy illustrations. The workers of the United States Department of Agriculture who are in a position to be familiar with the improvement program in the various states have led in the development of cooperative trials of new varieties that have made their rapid introduction possible.

Selection.—This is the basis of all improvement. Simple head selection from widely grown or newly introduced varieties has been an important source for varietal improvement. The variations found in commercial varieties may be due to mixtures, mutations, or segregation from natural crosses between varieties or species. The work of Burnett of the Iowa State Agricultural Experiment Station in his early oat-improvement program exemplifies the possibilities and successfulness of the selection method. Selection as a means of improvement is limited of course to the previous existence of a superior sort. If the population does not contain a superior type, then naturally it cannot be selected from the mixture. In addition to the complications that arise from the necessity of its presence, there is the added problem of being able to recognize the superior type even when it does exist. Even today, selection is an important part of improvement as it goes hand in hand with a program of hybridization.

Hybridization.—With most of the grains this is the common method of improvement. It offers the best possibilities, as there is an opportunity for the breeder to produce something that never existed before. Using his knowledge of genetics and other fundamental sciences, he can plan his program with definite objectives and with reasonable chances

for success. For example, if one wishes to produce a high-quality disease-resistant variety of wheat, he may achieve his goal by combining a low-quality disease-resistant variety with a high-quality disease-susceptible variety. This has been done in a successful and modern approach to plant improvement. Tama and Vicland oats were produced in this manner through the crossing of crown rust resistant low-quality Victoria with the crown rust susceptible high-quality Richland variety. After a cross is made, the breeder must practice selection in his choice of the more desirable material that is to be increased for further study.

Crosses between parental varieties that together have the desired characters and selection for a combination of these characters is the usual method used by the trained plant breeder. There are three general methods with minor modifications: (1) the pedigree method, (2) the bulk method, and (3) the backcross method.

In the pedigree method, planned crosses are made, and during the segregating generations, from F_2 until practical homozygosity has been obtained, the value of a particular selection is determined by growing separate progenies of selected plants in comparison with their parents and standard varieties. These may be grown under special environmental conditions, and epiphytotics of important diseases or infestations of particular insect pests may be practiced. Usually simple observations on disease or insect reaction and agronomic characters are made and plant selection continued until lines appear homozygous. Seed of desirable lines is bulked and tested for actual performance by carefully controlled yield trials.

In the bulk method, planned crosses also are used, but the progeny of each cross is usually grown in bulk plantings through the F_5 to the F_7 generation. At this time many plants will be homozygous, and these can be selected by growing and examining head row progenies. This method requires less study and expense during the segregating generations but requires large head progenies in order to obtain as great improvement for a cross as may be obtained by the pedigree method. Later tests of performance must be made as with material selected by the pedigree method.

The backcross method is especially desirable when one parent contains a preponderance of desirable characters. It may be crossed with a variety that has some characters that the desirable variety lacks. Backcrossing is made to the more desirable variety as a recurrent parent, and during the backcross generations selection is made primarily for the desirable characters of the nonrecurrent parent. Homozygosity for the characters of the recurrent parent is approached to a greater and greater

extent, depending on the number of factor pair differences and the number of generations of backcrossing. After obtaining relative homozygosity for the characters of the recurrent parent, it is necessary to grow plant progenies and select for homozygosity of characters obtained from the nonrecurrent parent.

FIG. 108.—The tools used by the plant breeder in hybridizing small grains. (*Courtesy of Coker's Pedigreed Seed Company.*)

METHODS OF MAKING A CROSS

The student of field crops should be interested in the mechanics of producing a new hybrid. While some deviations are followed by different breeders, the following methods as given by Hayes and Immer are typical of the usual methods employed.

Wheat.—The wheat flower, like other grass flowers, contains both the male and the female organs. Usually the spike is trimmed with a pair of scissors, leaving 8 to 10 spikelets which mature at about the same time near the center of the head. Prior to pollination, having chosen the two varieties to be crossed, the breeder removes the anthers, while they are green but beginning to turn yellow, with a pair of fine

pointed tweezers. After the flowers are emasculated, he covers the spike with a glassine bag about $1\frac{1}{2}$ by 6 in. in size. This bag is tied firmly to the plant and may be supported by a plant stake. The plant is marked with a small tag giving the name or number of the female plant (after emasculation it carries only female organs) and the date of the emasculation.

FIG. 109.—The pollen-bearing anthers are carefully removed to prevent self-fertilization. This in effect emasculates the flower. Next the pollen from the male parent is transferred to the emasculated flower. (*Courtesy of Coker's Pedigreed Seed Company.*)

About 2 days later, the pistil of the emasculated plant should be receptive to pollen. Accordingly, ripe anthers are taken from the variety that is to be used as the male. These anthers are held in the hand for a few moments, and if in the proper condition, they will burst. The glassine bag is removed from the female, and a bursting anther from the male is placed on the stigma of each emasculated flower. Next the glassine bag is replaced, the tag is marked with the name of the male parent and the date of pollination. The bag is not removed until time to harvest the matured seed. The seeds that develop will be hybrid

in nature, carrying the genetic characteristics of both parents. The disposition of this seed will be discussed a little later.

Oats.—The oat flower is treated in much the same way as outlined for wheat. In both grains the secondary florets are removed at the time of

FIG. 110.—After pollination, the head is securely covered with a glassine bag to keep out other pollen. The plant is properly tagged for identification. (*Courtesy of Coker's Pedigreed Seed Company.*)

trimming the spikelets. The panicle is trimmed to leave 15 to 20 spikelets. The oat flower is much more easily injured than that of wheat, so great care must be exercised. A somewhat larger bag, about $3\frac{1}{2}$ by 8 in., is needed for the oat, since the panicle is larger than the wheat spike.

After 3 to 4 days the emasculated flowers are pollinated in much the same way as with wheat.

Barley.—Usually it is necessary to pull the leaf sheath back, as the barley flowers are likely to be pollinated by the time that they emerge from the boot. In six-row barley, the lateral florets are removed and the spike is trimmed to 12 to 16 florets. The end of the floret is cut off just above the tips of the anthers, and the anthers are removed with fine pointed tweezers. One to two days later the flowers are pollinated, bagged, and labeled as with wheat and oats.

Rye.—This is a cross-pollinated plant, but it is treated much the same as wheat. Copious quantities of pollen are produced in the bag covering the pollen parent, and this is dusted on the female flowers about 4 to 6 days after emasculation.

Flax.—Usually, flax flowers are emasculated late in the afternoon and pollinated the following morning. Otherwise the methods are similar to those for wheat.

BREEDING SELF-POLLINATED PLANTS

The Pedigree Method.—As indicated above, the seed produced by hand pollination is hybrid seed. From our knowledge of genetics we know that following the recombination of characters in the cross we must expect segregation. It is necessary to carry the hybrids into several generations to determine whether the desired combinations have been fixed and then to test them for suitability as new varieties. The following steps indicate a general program that may be followed.

It is desirable to grow enough F_1 plants to provide the seed needed for the F_2 generation. The F_1 plants are grown in spaced hills to ensure maximum production. They may be grown in pots in the greenhouse and thus speed the program. The F_1 plants are compared with the parents, and those which appear to be self-pollinated are discarded.

In the F_2 grow a large number of individually spaced plants—Hayes and Immer suggest 2,000 to 10,000 F_2 plants.

Select individual plants on the basis of desired characteristics. Disease tests may be started in the F_2 and F_3 by subjecting the plants to artificial epidemics either in the greenhouse or field. Many stations use a special disease nursery where new lines are subjected to diseases with artificially created epidemics.

When the plants in a row appear homozygous and pass the tests for desirable agronomic characters and disease resistance, they may be combined or bulked. This is done usually in the F_4 to F_6 generations.

The homozygous bulked lines are placed in rod row trials, properly

replicated and tested for yielding ability and desirable agronomic qualities. In the case of wheat, milling and baking trials are made of a part of the harvested grain.

In some states, as in Minnesota, following adequate testing in the rod row nursery, the more promising lines are tested in larger plots, usually $\frac{1}{40}$ acre in size. Often these plots are placed in several locations to secure an adequate test of the suitability of the new lines to the different conditions that prevail in the state.

FIG. 111.—In breeding for rust resistance, specially constructed cages may be used for artificial inoculation during years when a natural epidemic does not occur. (*Courtesy of Coker's Pedigreed Seed Company.*)

After the variety has been tested adequately, the seed is increased and distributed to the growers. In many states the seed is placed in the hands of Approved Growers, farmers who have a good record in crop improvement and who may be expected to further the increase and rapid distribution of the new variety. Even under the most favorable conditions, it is usually 10 to 12 years after the cross is made before the variety is ready for distribution to the growers.

The Backcross Method.—The backcross method is a plan used by plant breeders when it is desired to add a plant character, which is conditioned by one or two genetic factors, to a variety that is otherwise satisfactory. It may be valuable also for more complexly inherited characters. Convergent improvement as used in corn for complexly inherited

characters is a backcross method. The general plan for simply inherited character differences as outlined by Hayes and Immer[1] follows:

1. Variety *A* is a suitable variety that lacks a character dependent upon only a few genetic characters, such as leaf rust resistance in wheat. Variety *B* is leaf rust resistant.

2. Variety *A* and variety *B* are crossed. The F_1, or $A \times B$ is backcrossed to *A*, and leaf rust resistant plants are selected from the progeny. The process is repeated as often as appears necessary to secure the desired

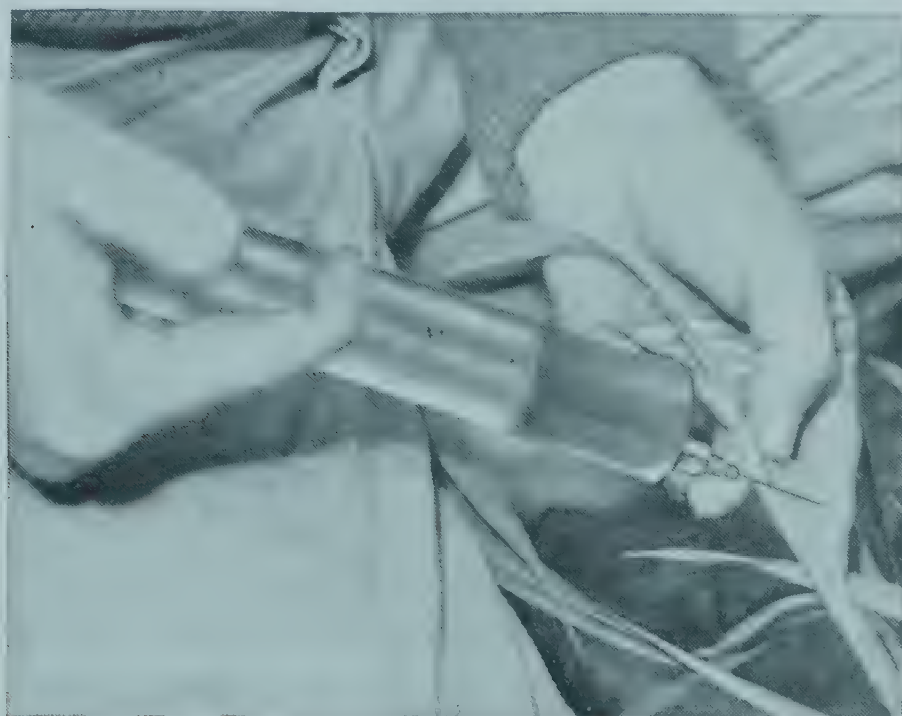


FIG. 112.—The plants may be subjected to attacks of rust by artificially inoculating them with spore suspensions in a hypodermic needle. (*Courtesy of Coker's Pedigreed Seed Company.*)

combination of desirable characters of *A* and the leaf rust resistance of *B*. The number of generations that the backcross must be made is directly correlated with the number of factor pairs involved. For example, with five factor pairs, after six generations of backcrossing, 92 per cent of the plants should be homozygous for the characters of the recurrent parent except leaf rust reaction, whereas with 10 factor pairs only 85 per cent should be homozygous for the factors from the recurring parent except leaf rust reaction.

3. Selection is made in the selfed progeny of the hybrid plants until homozygosity for the leaf rust resistance is obtained. The new lines

[1] HAYES, H. K., and F. R. IMMER, "Methods of Plant Breeding," McGraw-Hill Book Company, Inc., New York, 1942.

are compared with each other and with the parent A, and the most promising strain is increased and distributed as a new variety.

The backcross method as outlined by Briggs[1] should be reviewed by the student. Today the method is commonly used in the breeding programs of many research workers.

CROSS-POLLINATED CEREALS

Here the problem is greater than with self-pollinated crops, as it is very difficult to maintain a pure variety once it has been produced since crossing occurs readily.

Most of the rye varieties are the result of selection, as it does not appear economically feasible to make hybrids each year as is done with corn.

A general plan is as follows:

1. Select open-pollinated plants.
2. Study the progeny of selected plants and bulk similar selections.
3. Self-pollinate the selections, studying the inbred lines for desirable characters.
4. Combine the better inbreds, allowing them to cross-pollinate. It should be recognized that these lines will by no means be homozygous for all their characters.
5. Release the new variety, which should as far as possible be grown in fields isolated from other varieties of rye, or mixture will occur as a result of cross-pollination.

CORN

The work in corn improvement has done more to make the corn-growing farmer conscious of the benefits and possibilities of modern scientific plant breeding than most other crop-improvement activities. The effectiveness of plant breeding in the increase of corn yields has been discussed so widely that it is not unusual for a corn grower to understand many of the techniques of modern corn breeding.

MORPHOLOGY OF CORN

It is important that the student of corn improvement be familiar with the morphology of the corn plant. Reference to any good botany text will enable him to become familiar with pollination, fertilization,

[1] Briggs, F. N., Breeding Wheats Resistant to Bunt by the Backcross Method, *J. Am. Soc. Agron.*, **22**:239–244, 1930.

and the significance of double fertilization. Weatherwax[1] has given an excellent treatment of these phases in his book on corn.

Since corn is naturally cross-pollinated, common varieties of corn prior to the advent of hybrids were badly mixed or heterozygous in their genetic make-up. The separate location of the male and female flowers on the plant and the fact that usually a part of the pollen on a given plant is produced a little earlier than the silks are receptive to the pollen favors cross-pollination. Because of years of cross-pollination the so-called open-pollinated varieties were certain to be very heterozygous. In their heterozygous state they often carried many undesirable recessive characters that were perpetuated to continually reappear and in many cases to result in lowered yield or quality.

METHODS OF BREEDING CORN

The principal methods of corn breeding past and present are (1) mass selection, (2) ear-to-ear breeding, and (3) modern breeding resulting in hybrids.

Mass selection has been practiced since the earliest times. The Indian more or less consciously practiced mass selection and undoubtedly had made some improvements in the corn varieties he grew. For many years the farmers who selected their seed corn were using mass-selection methods.

The ear-to-ear method of improving corn gained many adherents. The plan was to grow and study the progeny of each ear selected in a single row and then to again select within the better producing rows. Various modifications were made of the method to reduce the close inbreeding, but today the method is of historical interest only.

The modern corn-breeding methods are based upon the science of genetics, and the breeder plans his program with the care and attention to detail of a builder. He used the tools of modern science to remove the guesswork from his operations and is able to predict with surprising accuracy the results that may be expected. It is important that the student understand the principles and applications of genetics and related sciences as used in corn improvement.

HYBRID CORNS

Although Beal, working in Michigan, suggested the use of crosses between strains of corn, the modern methods of corn breeding gained

[1] WEATHERWAX, PAUL, "The Story of the Maize Plant," University of Chicago Press, Chicago, 1923.

greatest impetus through the efforts of G. H. Shull, working at Cold Spring Harbor, N. Y., and E. M. East, working at the Connecticut Agricultural Experiment Station shortly after the turn of the century.

Following the leads given by Charles Darwin, Shull and East presented an entirely new approach to corn improvement. Through their inbreeding experiments they developed a new concept when they found that the inbreeding of corn resulted in an approach to homozygosity. These and related principles were to lead to a revolution in corn breeding that has produced remarkable results.

An excellent and very complete treatment of the early work leading to the present hybrid corn program was presented by East and Hayes[1] in 1912. They summarized the major results of inbreeding and selection as follows:

1. Continued self-pollination in all inbred lines of corn resulted in the loss of vegetative vigor.
2. Normal characters differ in different inbred lines; as, short ears, long ears, etc.
3. Inbred lines differ in vigor.
4. Some inbred lines are so weak that they cannot perpetuate.
5. Inbreeding if continued leads to purity of type.

Jones[2] amplified the earlier suggestions of Keeble and Pellew and Bruce, which explained hybrid vigor on the basis of Mendelian factors, in the light of further knowledge regarding the inheritance of quantitative characters. The use of double crosses for the commercial crop as suggested by Jones made the production of hybrid seed economically feasible.

SELECTION IN SELF-POLLINATED LINES

A selfed line is the closest form of inbreeding, where the pollen from the tassel is transferred to the silk on the same plant. There are certain basic principles involved in the uses of selfed lines.

1. Inbreeding makes controlled selection possible.
2. Corn as a result of its cross-pollination carries many undesirable as well as desirable characters.
3. Many of the undesirable characters are carried in the recessive condition.

[1] East, E. M., and H. K. Hayes, Heterozygosis in Evolution and in Plant Breeding, *U.S. Dept. Agr. Bull.* 243, 1912.

[2] Jones, D. F., Dominance of Linked Factors as a Means of Accounting for Heterosis, *Genetics*, **2**:466–479, 1917.

4. The recessives appear naturally in a field of open-pollinated corn at infrequent intervals because of the natural crossing that occurs.

5. Inbreeding reveals homozygous recessive characters and brings them out so that they may be eliminated, by selection for desirable dominant characters. It is of greater importance as a means of selecting the more vigorous inbreds.

6. Only the vigorous desirable inbreds are selected for further work. The most undesirable types are more or less automatically eliminated.

7. Plants that survive the selfing process become more homozygous as controlled self-pollination is continued.

8. Inbred lines are reduced in yield and vigor.

9. The superior selfed lines are selected and are used as material for hybridization.

HYBRIDIZATION

Having selected the most desirable lines for different periods of maturity, the breeder proceeds to combine inbreds so as to gain the vigor resulting from their combination. The greater the number of desirable growth factors that are brought together in the resultant hybrid, the greater will be its vigor. However, there is no reason to suppose that all growth factors are of equal importance.

The principles of hybridization may be summarized as follows:

1. When inbred lines are crossed with other unrelated inbred lines, each may contribute desirable growth characters that the other lacks, so that the resulting hybrid is more vigorous than the parents. The more different factors contributed by each, the greater the opportunity for a superior hybrid. Naturally, if two inbreds were very much alike in characters, their combination would prove of little or no advantage. For important characters such as time of maturity, disease reaction, and ability to withstand lodging, both parents may carry the same inherited factors.

2. The better selfed lines may be crossed with a variety to test their combining ability. This is frequently referred to as a *top cross*, a method widely used by corn breeders as a first test of selected inbred lines.

3. Having determined which lines are superior, lines of similar maturity and of unrelated genetic origin during the process of breeding are selected. These are then studied on single-cross combinations in actual yield trials. It has been learned that the breeding performance of particular double crosses may be determined by averaging the performance of single crosses. Thus characters expected in the double cross of

$(A \times B)$ $(C \times D)$ may be determined from the average performance for yield, plant height, or other characters of the four single crosses $A \times C$, $A \times D$, $B \times C$, $B \times D$.

The accuracy of prediction of such double crosses from single crosses has greatly simplified the preliminary testing of double-cross combinations. As Hayes and Immer illustrate, large numbers of double crosses can be predicted from relatively few single-cross yield trials. "Thus, for 20 inbred lines 190 single crosses can be made, and from the yield trials with these, one can predict the actual yielding ability of 14,535 double crosses."

4. Which lines are superior, having been determined, the inbreds are combined as single, three-way, or double crosses to produce hybrid seed corn.

TYPES OF CROSSES

The several types of crosses named above are used in various ways at the corn-breeding stations. It is essential that their uses and limitations be understood.

Single Cross.—The single cross results when two inbred lines are mated. The common practice is to assign a number or a letter symbol to each line as a means of identification. The female is usually designated first, as it is crossed by the male. Thus, $B \times A$ indicates that B, the female, was crossed by A, the male. As the inbred lines are reduced in vigor the plants and the ears they bear are small.

Since the ears are small and the seeds usually poorly shaped, the cost of production is great. The single crosses do produce the most uniform plants and ears and for this reason are especially suitable for the production of sweet corn for canning.

The Double Cross.—In the double cross, two single crosses are combined. Thus, $B \times A$, one single cross, is in turn crossed with $C \times D$, another single cross. Since both parents in the final cross are the result of single crosses, they are vigorous and produce large ears with a superior kernel type. The hybrid seed $(B \times A) \times (C \times D)$ is sold for the commercial crop. The superior seed of higher production reduces the cost and is favored by producers of hybrid seed corn.

Three-way Cross.—This is somewhat like the double cross except that a single cross such as $(B \times A)$ is crossed with an inbred line C. Usually, the single cross is used as the female and the inbred line as the male parent.

Top Cross.—The top cross is a means of evaluating lines. Usually an inbred is crossed with a good open-pollinated variety to test its value.

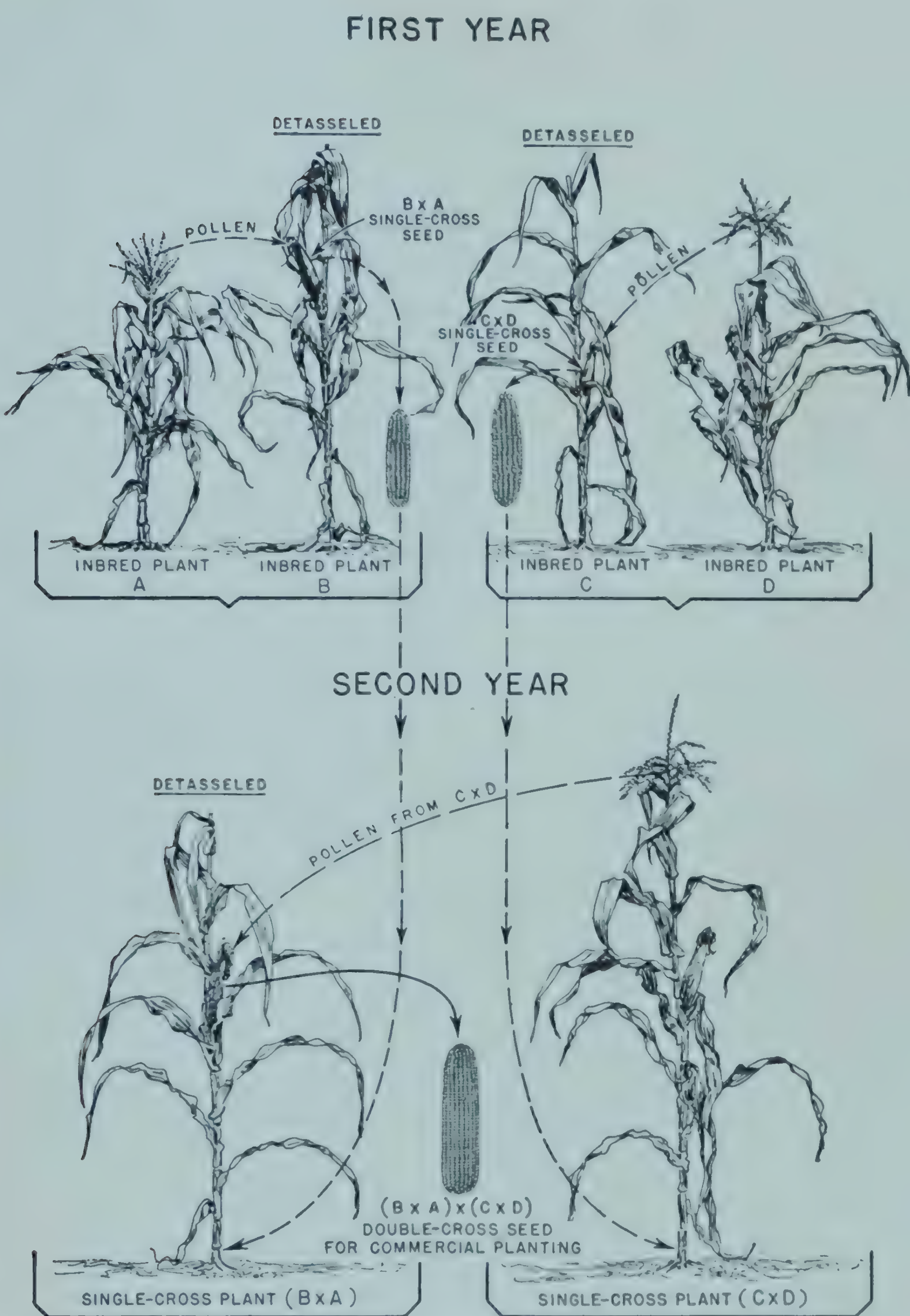


FIG. 113.—Diagram of method of crossing inbred plants and the resulting single crosses to produce double-cross hybrid seed. (*Courtesy of M. T. Jenkins, U.S. Department of Agriculture.*)

The use of the top cross in preliminary trials enables the breeder to get an earlier measure of the possible value of his inbred lines. Top crosses have been used in the past as the commercial crop, although on the average they yield less than three-way or double crosses.

THE COMMERCIAL PRODUCTION OF HYBRID CORN

The production of corn hybrids has led to a new industry, that of producing hybrid seed corn. Many of the large organizations as well as some farmers are engaged in the production of seed. The problems of seed production are such that the average farmer cannot afford to bother with producing his own seed but is much better off, as a rule, if he purchases his supplies from one who is making a specialty of the business. The methods followed in the production of the double cross are illustrated in the figure on page 361.

It is necessary to produce new crosses each year. If the seed is selected from the commercial crop, the yield may be expected to decrease 10 to 25 per cent in comparison with the yield of the double cross.

BREEDING IMPROVED INBREDS

The breeding of improved corn inbreds can be carried out in much the same manner as the breeding of self-pollinated plants, although it is necessary to practice controlled pollination.

Johnson and Hayes[1] describe the results of breeding improved inbreds by the pedigree method from a cross of inbred lines that together have desirable characters, where each parent excels in a character or characters that the other lacks. Selection in self-pollinated lines was continued through F_5 to F_6 until the lines appeared sufficiently homozygous so that they were ready for use in the breeding program.

Many corn breeders have used backcrossing as a method of corn improvement. The general consensus is that two or three generations of backcrossing should be practiced only if the breeder is very eager to change the characters of the inbred or if the characters are dependent upon multiple factors.

CONVERGENT IMPROVEMENT

As the pedigree and backcross methods were described in some detail in their application to self-pollinated plants, their application to corn will not be discussed further.

[1] Johnson, I. J., and H. K. Hayes, The Value in Hybrid Combinations of Inbred Lines of Corn Selected from Single Crosses by the Pedigree Method of Breeding, *J. Am. Soc. Agron.*, **32**:479–485, 1940.

Convergent improvement was suggested by Richey,[1] in 1927, as a method of improving each of two inbreds without greatly affecting their yielding ability when crossed together. The plan has been used in the improvement of corn, and according to Hayes and Immer, it is the equivalent of double backcrossing. They give the principal steps in convergent improvement as follows:

1. The breeder chooses a high-yielding desirable F_1 cross.
2. He backcrosses the F_1 to both of its parents and, in succeeding generations, backcrosses in two series to each of the respective parents.
3. During each year, he selects vigorous plants that possess desirable characters and uses these in the backcrosses.
4. He selects within selfed lines following several generations of backcrossing.
5. Next, using the superior inbreds recovered, he repeats the four steps to secure added improvement.

The method of convergent improvement has been used successfully in Minnesota in the corn-improvement program. Hayes and Immer state:

> The improvement of an inbred line by convergent improvement seems relatively easy for those characters in which it is seriously lacking, and the other inbred carries these characters. In two cases in which one of the inbred parents in a convergent improvement program was outstanding in smut resistance and lodging and gave a good yield for an inbred and in which the other parent was deficient in these characters and gave a low yield, it was relatively easy to improve the more undesirable parent through convergent improvement and rather difficult to obtain recovered lines that were superior or even equal to the more desirable parent in yielding ability and in other important characters.

Backcrossing as a method of breeding improved inbred lines has been used extensively in corn for complex as well as simple characters. Convergent improvement on the other hand has been used very little.

As stated earlier, most of the hybrid seed corn is produced by large operators who are well equipped to carry out the many details of pollination, harvesting, storage, grading, and marketing. These organizations employ personnel who are trained to carry out the exacting techniques pertinent to hybrid corn production.

The grower of hybrid corn must produce inbred lines or purchase these from other breeders. Next he must locate an isolated field to prevent cross-pollination with other corn. If possible the field should

[1] Richey, F. D., The Convergent Improvement of Selfed Lines of Corn, *Am. Naturalist,* **61**:430–449, 1927.

be 40 rods or more from the other field of corn, although natural barriers such as trees or buildings make it possible to reduce the distance. Generally two to four rows of the female parent are planted to every row of the male parent, the number varying with the vigor of the male parent and its ability to produce sufficient pollen. If the male parent is an inbred, fewer rows can be pollinated than if it is a single cross. A crossing field in which one male row was used to pollinate four female rows is illustrated.

Fig. 114.—A crossing field of hybrid corn. Four rows are detasseled to each row not detasseled. The one row furnishes pollen for the four detasseled rows. All ears produced on the detasseled rows will be hybrids. (*Courtesy of M. T. Jenkins, U.S. Department of Agriculture.*)

By removing the tassels prior to the time they produce pollen, inbreeding is prevented and the plants are crossed naturally by the male plants. Workers go through the fields at regular intervals to remove all tassels from the female rows. All the corn produced on the female rows will be hybrid and may be saved for seed.

Following harvest the seed corn should be dried. In many sections the growers use specially constructed driers so as to ensure a good job. When dry the corn is shelled and graded into different sizes and shapes, tested for germination, and bagged for sale. Regardless of size or shape most kernels are suitable for seed except that the odd-shaped kernels are not as easily planted. The manufacturers of corn planters make special plates for each grade of corn, and the processor gives the necessary information to the buyer. Usually the more desirable grades, such as the medium flats or large flats, sell for a higher price than such grades

as large rounds, which are irregularly shaped kernels coming primarily from the ends of the ear.

It is necessary for the producer of hybrid corn to maintain his inbred lines or to secure new lines each year. These lines may be maintained by growing them in isolated plots or by the use of bags and hand pollination.

DOES HYBRID CORN PAY?

Even today a few farmers raise this question, but generally the results have been so striking that in the important corn states open-pollinated varieties have disappeared almost entirely. Since many of the hybrids yield 15 to 20 per cent more grain, it is evident that few farmers will fail to take advantage of the opportunity to so greatly increase their production. The percentage of marketing ears is greater with the hybrid varieties, and much progress has been made in breeding for disease resistance as well as such desirable agronomic characters as extensive root systems and strong stalks. While the price per bushel of seed corn may appear to be large, when one considers the small cost of seed per acre and the many advantages, he is impressed with the fact that where hybrids are available the farmer cannot afford to do without them.

SWEET CORN HYBRIDS

The use of hybrids in the sweet corn canning industry has gained great favor. Most of the successful sweet corn hybrids are single crosses which give great uniformity in the high percentage of satisfactory ears. This uniformity of maturity is especially important, since a field for canning must be harvested at one time. Uniformity means much less waste in the harvesting of immature and overmature ears. In some trials, yields of cut corn have been 50 per cent more than those secured from the open-pollinated varieties.

Several of the state agricultural experiment stations are carrying on intensive sweet corn breeding programs. Certain of the large canning and seed companies have well-organized programs that have resulted in decided improvements in yield and quality of product.

While yield of cut corn is a factor of major importance, great improvement has been made in the production of hybrids whose kernels have more tender seed coats and are superior in palatability and sweetness.

POPCORN HYBRIDS

Popcorn hybrids have not been developed so extensively as the other corns since the industry is more limited. However, popcorn may be improved by methods similar to those outlined for field corn. Several

promising hybrids have been developed. Emphasis has been placed on increased volume of popped grains and improved quality.

Brunson and Smith[1] have reviewed the status of popcorn hybrids. They report that average yield increases range from 9 to 68 per cent. In all hybrids tested the popping expansion was better than the corresponding open-pollinated strains in the trials. The trade has recognized the superiority of hybrids and has paid a premium for corn from the better ones.

SORGHUM

Few crops have undergone more rapid and remarkable improvement than sorghum. In the less than one hundred years it has been grown in the United States, sorghum has been literally made over. Out of the original introductions, which for the most part were ill-suited for American conditions, have come a host of varieties adapted to specific areas and suitable for specialized purposes.

OBJECTIVES IN BREEDING FOR IMPROVEMENT

One of the principal aims in sorghum breeding is the development of varieties that are well adapted in the region in which they are to be grown. The need for improvement in this respect has been apparent especially in the central and northern Great Plains. Sorghum is a hot-weather crop, and while the varieties first introduced did well in the southern Great Plains, they did not succeed in the areas farther north. Progress has been made, as is indicated by the fact that varieties are now available which will produce ripe grain in the relatively short, cool growing season found in the high-plains region of northwestern Kansas, northeastern Colorado, and western Nebraska.

Hand harvest of grain sorghum is perhaps even more laborious than hand husking of corn. Growers therefore want varieties that can be harvested with machinery, preferably the combine. Therefore a second objective is the development of dwarf varieties that will be suitable for harvesting with the combine.

Finally, in addition to the factors of yield and quality, which must always be considered, the sorghum breeder is faced with the need for breeding varieties that are resistant to the important diseases and insects. For example, a few years ago, *Pythium* root rot threatened to prevent completely the growing of milo in the southern Great Plains. But the timely development of resistant varieties that are satisfactory in other

[1] Brunson, A. M., and G. W. Smith, Hybrid Popcorn, *J. Am. Soc. Agron.*, **37**: 176–183, 1945.

characteristics has apparently eliminated this threat. Still needed are varieties that are resistant to smut, charcoal rot, and chinch bugs.

METHODS OF BREEDING

It has been noted previously that sorghum is placed in the group of often cross-pollinated crops. There is considerable variability in the extent of cross-pollination in sorghums, Karper and Conner[1] reporting 6 per cent and Sieglinger[2] slightly more than 5 per cent in milo, while Ball[3] suggests that there may be as much as 50 per cent. With the exception that precautions must be taken to prevent natural crossing, the methods used in sorghum breeding are in general the same as those used in breeding naturally self-pollinated crops.

Introductions, mainly from Africa, have been the source of all sorghum now grown in the United States. Some varieties of commercial importance, such as Blackhull Kafir, Feterita, and Hegari, are now used in what is apparently much the same form as when they were first introduced. Still other varieties have resulted from the selection of fortuitous mutations and of chance combinations of favorable characters following natural cross-pollination. There are many varieties that have been developed in this way, some of them being Dwarf Yellow Milo, Western Blackhull Kafir, Finney Milo, Westland, and Early Hegari.

As with the other grain crops, controlled hybridization followed by selection in the segregating progeny has been used with marked success. The technics used in producing the hybrids are fundamentally the same as those previously described for wheat, barley, and oats. Twenty-four to forty-eight hours in advance of the time it is judged that the flowers will open, anthers are removed with a pair of fine-pointed forceps from the flowers on one or more branches of a panicle on the plant to be used as female parent. These flowers are then covered with a small glassine or cellophane bag. Early in the morning of the first or second day following emasculation the glumes will open naturally, exposing the feathery stigmas. At that time pollen is gathered from the plant to be used as male parent and is applied to the stigmas of the emasculated flowers. The protective bag is replaced and is left in place until any danger of fertilization by unwanted pollen is past. Following hybridization, selection of desirable plants is carried on in the segregating gener-

[1] Karper, R. E., and A. B. Conner, Natural Cross-pollination in Milo, *J. Am. Soc. Agron.*, **11**:257–259, 1919.

[2] Sieglinger, J. B., Cross-pollination of Milo in Adjoining Rows, *J. Am. Soc. Agron.*, **13**:280–282, 1921.

[3] Ball, C. R., The Breeding of Grain Sorghums, *Am. Breeders' Mag.*, **1**:283–293, 1910.

ations, as has been described for the small grains. During this process it is necessary to cover the panicles of selected plants with paper bags in order to prevent cross-pollination. Selections are continued in pedigree cultures until they have become relatively homozygous, *i.e.*, until the progeny of a selection is uniform. Strains developed in this way, which appear on visual inspection to be superior to the standard varieties, are then included in yield trials and are examined critically with respect to all characteristics of importance. Only those strains which meet all these tests successfully are multiplied, named as varieties, and distributed. Colby, Sooner, and Wheatland were developed in this way from crosses made by John B. Sieglinger at the Southern Great Plains Field Station, Woodward, Okla. Early Kalo was developed by A. F. Swanson at the Fort Hays Agricultural Experiment Station, Hays, Kans. Quadroon, Caprock, Plainsman, and Bonita were developed at the Texas Agricultural Experiment Station by R. E. Karper, J. R. Quinby, and J. C. Stephens.

First-generation hybrids between certain sorghum varieties exhibit extreme vigor and uniformity, comparable to that found in corn hybrids.[1] If this vigor could be utilized, as it now is in corn, it would be of tremendous importance to the sorghum grower. So far, the cost of producing hybrid sorghum seed by hand has precluded its use by farmers. But Stephens[2] has reported the occurrence of heritable male sterility in sorghum and has suggested a procedure by which it may be used in producing hybrid seed. Certain troublesome problems must be dealt with before this procedure becomes a reality, but it would seem justifiable to believe that they will eventually be solved.

MAINTENANCE OF VARIETAL PURITY

Because sorghum belongs to the group of often cross-pollinated crops, it is more difficult to keep varieties of it free of mixture than is true of crops in the self-pollinated group. Furthermore, mixtures resulting from cross-pollination are particularly undesirable in sorghum because there is such great variability in the crop and because all types and varieties, including Sudan grass and broomcorn, hybridize freely. In a field of a supposedly pure variety, hybrids resulting from natural crossing not only detract from the appearance of the crop, but they cause difficulty in harvest, and they may result in a lowered market grade.

In order to produce a crop free of hybrid mixtures it is necessary

[1] KARPER, R. E., and J. R. QUINBY, Hybrid Vigor in Sorghum, *J. Heredity*, **28**: 83–91, 1937.

[2] STEPHENS, J. C., Male Sterility in Sorghum: Its Possible Utilization in Production of Hybrid Seed, *J. Am. Soc. Agron.*, **29**:690–696, 1937.

to prevent cross-pollination. This may be done by isolating the seed field from other sorghums, so that there is a minimum of contamination. Seed produced under certification according to the rules established by the certifying agencies in the various states is generally as pure as can be obtained.

QUALITY SEED

Every student should be interested in the production of superior-quality seed. It is not enough to start with pure seed of an adapted variety. Too often such originally high-quality seed is permitted to become badly mixed with other crop seeds, other varieties of the same crop, and weed seeds. Several organizations have organized for the express purpose of improving the quality of seed.

The principal groups especially interested in quality seed are (1) the state crop improvement associations, (2) commercial crop improvement associations, and (3) various farmers' cooperatives.

STATE CROP IMPROVEMENT ASSOCIATIONS

The crop improvement association as organized in most states has as its objective the raising of the level of seed quality. For example, the objectives of the Minnesota Crop Improvement Association, as stated in its constitution, are as follows:

1. To collect and disseminate information concerning the growing, harvesting, storing, and handling of seeds of the staple crops.
2. By selection and breeding to improve the yield and quality of all crops.
3. To encourage better and more thorough methods of cultivation.
4. To publish the transactions of all meetings and other information of interest to farmers and gardeners.
5. To aid the organization of subordinate and auxiliary associations throughout the state.

Effectiveness.—The Minnesota Crop Improvement Association has carried out the various objectives with the exception of the second. This work has been left to the research workers in the agricultural experiment station. In many ways the association has aided the work of the experiment station in that it generally recognizes and certifies seed only of varieties receiving the approval of the research staff.

A regular publication is issued to the membership. This publication carries articles of interest to the members, announcement of meetings, regulation procedures, and otherwise serves as a service organ to its subscribers.

Seed Certification.—One of the major activities of most crop improvement associations is the work of seed certification.

Certified seed has been defined by Frolik and Lewis[1] as "seed of known superior heredity and quality verified by and traceable through the periodic inspection and records of an impartial and officially recognized agency."

Seed certification is a recognized part of crop improvement in nearly every one of the states. Fisher[2] estimated that in 1942 approximately 31 million bushels of seed were certified in the various states. Undoubtedly this has done much to raise the level of the quality of the seeds in the sections where certification was practiced.

Classes of Seed Certified.—The common classes accepted by most state associations are (1) foundation stock seed, (2) registered seed, and (3) certified seed.

1. Foundation seed is seed so handled as to maintain most nearly specific genetic identity and purity, which may be distributed by an agricultural experiment station. Production must be carefully supervised or approved by representatives of an agricultural experiment station. Such seed shall be the source of all other certified seed classes, either directly or through registered seed.

2. Registered seed is really the progeny of foundation or registered seed that is so handled as to maintain satisfactory genetic identity and purity and that has been approved and certified by the certifying agency.

3. Certified seed is the progeny of foundation, registered, or certified seed, so handled as to maintain satisfactory genetic identity and purity and that has been approved and certified by the certifying agency.

In most cases the acceptance of the seed for certification is based upon field inspections for purity and a later check on the threshed sample as to its purity and ability to germinate.

While each state association has its own organization, the general program is somewhat as outlined above.

THE INTERNATIONAL CROP IMPROVEMENT ASSOCIATION

In 1910, the various state crop improvement associations joined to form the International Crop Improvement Association. The objectives of this organization as stated in its constitution are as follows:

> . . . to promote the agricultural interests of the various states and provinces of America, emphasizing especially the improvement of field crops in general and seed improvement in particular by:

[1] Frolik, E. F., and R. D. Lewis, Seed Certification in the United States and Canada, *J. Am. Soc. Agron.*, **36**:183–193, 1944.

[2] Fisher, O. S., Progress Report on Certifying Agencies, *Intern. Crop Improvement Assoc., Ann. Rept.*, **23**:54–64, 1941.

(1) Encouraging the breeding and improvement of field crops and seeds.

(2) Husbanding, propagating, and disseminating Elite, Registered, Certified, and Improved seeds.

(3) Creating a more active interest in better seeds through circulars, reports, and other publicity, as well as encouraging local, state, and international shows.

(4) Assisting in the standardization of the seed improvement work being done by member organizations.

About 35 states and provinces are members of the International Crop Improvement Association. The organization has done much to standardize certification rules on basic principles. Many state organizations now accept certified seed from other states on the basis of the certification at the point of origin. The benefits of such cooperative arrangements both to the buyer and the seller are evident.

COMMERCIAL CROP IMPROVEMENT ASSOCIATIONS

These are organizations of businessmen interested in the furtherance of the production of high-quality crops. For example, the Northwest Crop Improvement Association with headquarters in Minneapolis employs a full-time secretary who spends his time furthering the production of high-quality grains that come to the Minneapolis market.

The organization sponsors farmers' seed schools and other educational programs. One of the effective projects of the Northwest Crop Improvement Association is its cooperation with the Minnesota Crop Improvement Association in the selection of men who have outstanding records as producers of quality seed. These individuals are named Premier Seedgrowers. The general effect of such a program is to encourage the production of higher quality seed throughout the state.

COOPERATIVE ORGANIZATIONS

In several of the states, various cooperatives carry on planned programs of encouraging the production of quality seed and the use of adapted varieties. Some of these organizations employ full-time men to carry their programs to the people. In general, their efforts are correlated with the activities of the agricultural experiment stations and the extension staffs so as to supplement their activities.

References

Ausemus, E. R., M. C. Markley, C. H. Bailey, and H. K. Hayes: Quality Studies in the Wheat Breeding Program at the Minnesota Agricultural Experiment Station, *J. Agr. Research*, **56**:453–464, 1938.

Borgeson, Carl, and H. K. Hayes: The Minnesota Method of Seed Increase and Seed Registration for Hybrid Corn, *J. Am. Soc. Agron.*, **33**:70–74, 1941.

BREWBAKER, H. E.: Studies of Self-fertilization in Rye, *Minn. Agr. Expt. Sta. Tech. Bull.* 40, 1926.

BRIGGS, F. N.: The Use of the Backcross in Crop Improvement, *Am. Naturalist*, **72**: 285–292, 1938.

CLARK, J. A.: Improvement in Wheat, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

DILLMAN, A. C.: Improvement in Flax, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

ECKHARDT, R. C., and A. A. BRYAN: Effect of Method of Combining the Four Inbred Lines of a Double Cross of Maize upon the Yield and Variability of the Resulting Hybrid, *J. Am. Soc. Agron.*, **32**:347–353, 1940.

HARLAN, H. V., and M. N. POPE: The Use and Value of Backcrosses in Small Grain Breeding, *J. Heredity*, **13**:319–322, 1922.

HARRINGTON, J. B.: The Mass-pedigree Method in the Hybridization Improvement of Cereals, *J. Am. Soc. Agron.*, **29**:379–384, 1937.

HAYES, H. K., and I. J. JOHNSON: The Breeding of Improved Selfed Lines of Corn, *J. Am. Soc. Agron.*, **31**:710–724, 1939.

IMMER, F. R.: Relation between Yielding Ability and Homozygosis in Barley Crosses, *J. Am. Soc. Agron.*, **33**:200–206, 1941.

IVANOFF, S. S., and A. J. RIKER: Resistance to Bacterial Wilt of Inbred Strains and Crosses of Sweet Corn, *J. Agr. Research*, **53**:927–954, 1936.

JENKINS, M. T.: Corn Improvement, *U.S. Dept. Agr., Yearbook of Agriculture*, 1936.

JOHNSON, I. J., and H. K. HAYES: The Combining Ability of Inbred Lines of Golden Bantam Sweet Corn, *J. Am. Soc. Agron.*, **28**:246–252, 1936.

JONES, D. F., and W. R. SINGLETON: The Improvement of Naturally Cross-pollinated Plants by Selection in Self-fertilized Lines. II. The Testing and Utilization of Inbred Strains of Corn, *Conn. Agr. Expt. Sta. Bull.* 375, 1935.

MEYERS, M. T., L. L. HUBER, C. R. NEISWANDER, F. D. RICHEY, and G. H. STRINGFIELD: Experiments on Breeding Corn Resistant to the European Corn Borer, *U.S. Dept. Agr. Tech. Bull.* 583, 1937.

MORSE, W. J., and J. L. CARTTER: Improvement in Soybeans, *U.S. Dept. Agr., Yearbook of Agriculture*, 1937.

RATHER, H. C.: Multiplication of Improved Seed through Seed Associations, *J. Am. Soc. Agron.*, **20**:15–22, 1928.

REED, G. M.: Physiological Races of Oat Smuts, *Am. J. Botany*, **27**:135–143, 1940.

RICHEY, F. D.: The Convergent Improvement of Selfed Lines of Corn, *Am. Naturalist*, **61**:430–449, 1927.

SHULL, G. H.: A Pure Line Method of Corn Breeding, *Am. Breeders' Assoc. Rept.*, **5**:51–59, 1909.

———: Hybridization Methods in Corn Breeding, *Am. Breeders' Mag.*, **1**:98–107, 1910.

SMITH, L. H., and A. M. BRUNSON: An Experiment in Selecting Corn for Yield by the Method of the Ear-row Breeding Plot, *Ill. Agr. Expt. Sta. Bull.* 271, 1925.

STAKMAN, E. C.: A Study of Cereal Rusts: Physiological Races, *Minn. Agr. Expt. Sta. Bull.* 138, 1914.

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